ATTACHMENT B

STAFF PAPERS ON PETROLEUM REDUCTION OPTIONS

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INTRODUCTION

This Attachment B (Staff Papers on Petroleum Reduction Options) provides supporting background information for the analysis presented in the report entitled ***Task 3: Petroleum Reduction Options***. The Task 3 report is part of a larger effort being conducted by the Energy Commission and the Air Resources Board to develop strategies and recommendations to establish statewide petroleum reduction goals.

Although there may be some duplication with the abbreviated versions provided in the Task 3 report, this compilation of the original staff papers provides additional detail and discussion on each option. This compilation also includes a summary table for appropriate options that provides major input assumptions and results of the analysis. The methodology behind the summary tables is described in detail in Attachment A (Methodology); however, the description of the columns is repeated here for the reader's convenience.

Each of the options in Group 2 (and Option 1E) used a series of spreadsheets to calculate the effect of discounting future costs and savings (Present Value). The results of these spreadsheets are presented in this report in Attachment B as a "Summary Sheet" for each option.[1] Each summary sheet is divided into two major areas: (1) Major Input Assumptions (on the right-hand side) and (2) Results of the Analysis (on the left-hand side).

Although the staff assumed that each of the Group 2 options could achieve a 10 percent market penetration in new vehicle sales for comparison purposes, specific deployment strategies that might be required to reach this penetration level have not been evaluated. If market-based scenarios were to be created with sufficient confidence and detail, staff could then make a reasonable estimate of the option's economic outcomes, including the effects of the strategy, using the methodology previously described.

1. Major Input Assumptions

For Conventional Vehicles:

- **Fuel Economy.** For conventional light-duty gasoline vehicles, we assume an average fuel economy of 21.2 miles per gallon, consistent with our base case forecast. For light-duty diesel vehicles, we assume a 45 percent improvement in miles per gallon compared to the average gasoline vehicle, or 30.7 miles per gallon of diesel.

- **High and Low Fuel Price Estimate.** Projected long-term gasoline fuel prices are constant at $1.64 per gallon, with a range of $1.47 to $1.81 per gallon (in 2001 dollars) to reflect the mean price plus and minus one standard deviation based upon historical price fluctuations. Corresponding diesel prices are $1.65 per gallon with a range of $1.48 to $1.82 per gallon.

For Each Option:

For the technology analyzed in each option, we assume the fuel economy, incremental capital cost, and projected fuel price range specific to the technology. Refer to the discussion of each option for more information on its assumptions.

- **Vehicle Fuel Economy.** Refer to the discussion in each option for more information on these assumptions.

- **High and Low Incremental Capital Cost.** The option's capital cost is shown relative to the cost of the conventional vehicle it would replace.

- **High and Low Fuel Price.** The option's fuel cost is determined as follows. First, the wholesale price is determined by using historical data to find the "Sale to Resellers" or some other wholesale price. For example, the Sale to Resellers price is available for LPG, as a national average, from the U.S. Department of Energy's Energy Information Administration web site.[2]

  First, staff derived the average wholesale price and one standard deviation. This yields a "high" and "low" fuel price range. Then staff assumed this price range can be used to represent future wholesale costs. This is done to be consistent with our gasoline and diesel future price forecasts where staff assumed essentially flat gasoline and diesel wholesale prices over the time period.

  For LPG, staff assumed that sufficient additional volumes could be made available for an additional price of 15 cents per gallon, to "bid it away" from traditional industrial users in the Gulf Coast and transport it to California. Then staff assumed that the dealer receives the same price mark-up per gallon as gasoline, another 15 cents per gallon. Finally, staff assumed that existing excise and sales taxes are added to determine the retail price.[3] See Option 2E discussion for more details.

- **Vehicle Life.** For light-duty vehicles, staff assumed a 15-year vehicle life, with 16,500 miles per year in the first year of operation and usage decreasing as the vehicles age, reaching 5,764 miles per year by the 15th year, for a total of 147,308 miles over the vehicle life. These assumptions are consistent with CALCARS. For heavy-duty vehicles, staff assumed a 16-year vehicle life and annual mileage that varies by type of vehicle.

- **Discount Rate.** As noted above, staff used a 5 percent discount rate to calculate net present value.

- **Option's Vehicle Deployment.** Staff determined a vehicle deployment rate needed to ramp up to 10 percent new vehicle sales (see discussion below).[4] Each option's summary table contains a deployment graph showing annual vehicle sales, fuel displaced and cumulative vehicles sold.

2. Analysis Results

Staff provides results with a range of outputs. Staff calculated a range of fuel prices from the expected mean price plus and minus one standard deviation. Staff determined one end of this range by assuming high option fuel and capital costs and determined the other end of this range by assuming low option fuel and capital costs. The results of the analysis are shown on the Summary Sheet for the three time periods.

Present Value Million 2001 Dollars Saved Over Time Period. Results are first shown as present value dollars (2001 dollars) as a range of expected Net Consumer Benefits, Change in Government Taxes, and the Net Benefits (see definitions for these columns below).

Conventional Fuel Displaced. This column shows results in terms of cumulative million gallons of conventional fuel displaced over the same time periods and in specific target years (2010, 2020 and 2030).

2001 Dollars Per Gallon of Conventional Fuel Displaced. For target years 2010, 2020 and 2030, the table shows the benefits (savings or costs) for that year (not in present value terms) divided by the gallons displaced in that same year. Positive values represent savings and negative values (in parentheses) represent costs, both in dollars and dollars per gallon.

- **Net Consumer Benefits.** As described above, staff compared high fuel and incremental capital costs at one end of the range and low fuel and capital costs at the other end of the range. For easy comparison, staff subtracted the fuel savings (or costs) from the annualized capital cost to determine net consumer benefits per vehicle. Incremental capital costs were annualized using the 5 percent discount rate, a 15-year vehicle life (16 years for heavy-duty vehicles), and payment at the beginning of each year.

  A negative fuel savings represents the case when the alternative fuel vehicle's annual fuel cost is higher than the cost of fuel for the conventional vehicle and may result in the Net Annual Savings becoming negative. This result is expressed in parentheses to reflect the negative value. Annual fuel savings (or costs) decrease annually during the 15 years of vehicle life as the vehicle is driven less each year it ages.

- **Change in Government Taxes.** Existing taxing requirements and the federal ethanol subsidy were assumed to remain throughout the 2002 to 2030 time period, although significant non-petroleum fuel use could cause these tax requirements to change in ways we cannot anticipate at this time.

- **Net Benefits.** A combination of the "Net Consumer Benefits" column and the "Change in Government Taxes" column.

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[1] For electronic copies of these spreadsheets, please call the Transportation Technology Office or see the Energy Commission's web site at http://www.energy.ca.gov/fuels/petroleum_dependence.

[2] http://www.eia.doe.gov.

[3] For electricity and natural gas, the methodology is essentially the same, except we use Energy Commission forecasted commercial end use prices for each service area to determine the high and low price range. For electricity, we assume that off-peaking charging costs 60 percent of the average rate. For natural gas, we assume an additional 32 cents per therm of natural gas dispensed, based upon commission contract experiences. This covers O&M, electricity for running the compressors, labor, etc. (References: CEC price forecast reports and Transportation Technology Office program data.)

[4] Staff assumed a nominal 4 percent displacement of conventional fuel by 2010 and 10 percent by 2020 (Options 2D, 2E, 2F, 2G, 2H, 2I and 2J). For the remaining options (2A, 2B and 2C), staff assumed the 4 percent displacement value is reached in 2020 and the 10 percent value is reached by 2030.

Staff Paper on Option 1A
Improved Vehicle Fuel Economy

Description

This option is based on increasing light-duty vehicle efficiency by means of advanced vehicle technologies. The technologies covered include advanced internal combustion engines, hybrid-electric propulsion, 42V electrical systems, integrated starter-generators as well as a myriad of other improvements that enhance fuel economy relative to more traditional vehicle equipment. Increasing fuel economy levels provides the opportunity to meet transportation demand with less fuel. As a result, increasing vehicle efficiency, particularly in mass-production vehicles that constitute the majority of transportation energy demand, can result in significant petroleum reductions.

Background

Fuel economy improvements for commercially viable, production-volume vehicles is a topic that has had significant attention and study. Due to the significant capital investments in vehicle manufacturing, as well as the product cycles of automobiles, most work examining changes in automotive product offerings consider scenarios for several years in the future. We used vehicle fuel economy analyses performed by the American Council for an Energy-Efficient Economy[1] (ACEEE), the National Research Council[2] (NRC), and Energy and Environmental Analysis, Inc.[3] (EEA) to develop ten cases for potential future fuel economy improvements. Staff supplemented the ACEEE mild hybrid and full hybrid vehicle costs with cost estimates prepared by ARB staff. These works were consulted as they collectively provide a range of potential incremental technology costs and fuel economy levels. The findings of these studies are used to estimate a range of petroleum demand reductions that are possible for California.

One of the NRC report findings is that incremental improvements occur each year, but that significant changes, such as major fuel economy improvements, take decades to penetrate the market in significant quantities. This factor was used in determining the timing of introducing new fuel efficiency technologies in the analysis below.

In order to translate technology improvements into real world fuel economy improvements, consumers will have to decide that vehicles have attained sufficiently improved performance, and that further technology improvements are worth the extra price they will require. The ACEEE, NRC, and EEA studies together consider several technology levels or “packages” that could be used to achieve improved vehicle fuel economy. These packages include various technologies and are not limited to a particular device or implement. Rather, these technology options are assembled into systems that would collectively deliver improved fuel economy. Each is described below.

ACEEE Study. The stated purpose of the ACEEE study was to provide an assessment of “technically optimum” applications of affordable vehicle efficiency improvements to allow policy makers to make more informed decisions. The ACEEE study did not include plug-in hybrid vehicles. The authors defined four vehicle fuel economy improvement treatments as follows:

1. **Moderate** (29.9 mpg weighted average fuel economy). This treatment uses current trends in the automotive industry to apply improvements that improve fuel economy, including some improvements now intended primarily to enhance performance rather than fuel economy.[4] These include:

    - mass reduction (0 percent for small cars, 10 percent for mid-sized cars and 20 percent for minivans, pickups and SUVs);
    - aerodynamic streamlining to reduce drag 10 percent;
    - more use of low rolling resistance tires (for 20 percent less rolling resistance);
    - more efficient accessories;
    - an advanced, high-efficiency gasoline engine (50kW/L in place of the current 43 kW/L, without direct injection);
    - integrated starter-generator with 42-volt system; and
    - improved electronically controlled transmissions (continuously variable transmissions for cars and 5-speed automatics for trucks).

    No size reductions are needed. However, small cars become slightly larger. Some of these options have already entered the market.

2. **Advanced** (34.4 mpg). This treatment extends the Moderate treatment by using:

    - more mass reduction (10 percent for small cars, 20 percent for mid-sized cars and 33 percent for minivans, pickups and SUVs);
    - the same streamlining, low rolling resistance tires and accessory improvements as the moderate treatment;
    - an advanced, direct-injection gasoline engine (55 kW/L);
    - the same integrated starter-generator with 42-volt system as the moderate case; and
    - advanced electronically controlled transmissions (continuously variable transmissions for cars and 6-speed transmissions for other vehicles, all fully optimized for low emissions, low fuel consumption and low road-load operation).

    Advanced, compact and integrated engine-transmission power trains contribute to weight reductions, but SUV mass reductions also require new materials.

3. **Mild Hybrid** (39.9 mpg). This treatment assumes that mild hybrids will extend the advanced treatment by adding a hybrid-electric power train and electric power for 15 percent of peak power to achieve 15 to 18 percent further fuel economy improvements.[5] The Honda Insight hybrid vehicle, with an aluminum body, is identified in the report as “an Advanced Package platform.” Two categories of incremental vehicle costs are used for each of six vehicle classes. One price category is directly from the ACEEE report and represents an evolutionary process of future cost reductions as the market matures. The other price category is labeled “ARB” and represents a more aggressive cost reduction pathway,

especially requiring major cost reductions for motor-controller hardware, offset somewhat by the cost of a mid-life battery replacement.

4. **Full Hybrid** (45.0 mpg). This treatment extends the mild hybrid treatment by using electric power for 40 percent of peak power to achieve 29 to 33 percent fuel economy improvement over the advanced treatment. Two price categories are used, as discussed above for mild hybrid vehicles.

NRC Study. The NRC study developed three successively more aggressive (and costly) product development paths that include both production-intent[6] and emerging[7] technologies. Emerging technologies are identified below with a (E). Treatments vary for various vehicle classes. Common to all three paths discussed below and for most vehicle classes within them are reduced engine friction, low friction engine lubricants, variable valve timing, more efficient engine accessories, improved rolling resistance tires and reduced aerodynamic drag. Also, all include the effects of a 5 percent vehicle weight increase for safety (and an associated fuel economy penalty). The NRC study did not include any hybrid or diesel vehicles. The authors defined three vehicle fuel economy improvement Paths (treatments) as follows:

1. **Path 1** (23.2 mpg). Path 1 uses mostly competition-driven, production-intent technologies available at current fuel prices. Vehicle performance is held constant. Specific treatments include:

   - multi-valve overhead camshafts for larger vehicles;
   - 5-speed automatic transmissions with advanced shift logic;
   - cylinder deactivation in SUVs and small pickups; and
   - 42-volt electrical systems in passenger cars (E).

2. **Path 2** (27.9 mpg). This path extends Path 1 by using more costly production-intent technologies that will only become economically feasible if fuel prices rise; they also make greater use of emerging technologies. Specific treatments include:

   - multi-valve, overhead camshafts for larger vehicles;
   - variable valve lifting and timing;
   - cylinder deactivation for SUVS and pickups;
   - 5-speed or 6-speed automatic transmissions for larger vehicles;
   - continuously variable transmissions for smaller vehicles;
   - intake valve throttling (E);
   - automatic shift manual transmissions (except subcompacts and compacts) (E);
   - 42-volt systems (except subcompacts and compacts) (E); and
   - electric power steering (except subcompacts, compacts and small SUVs) (E).

3. **Path 3** (31.4 mpg). Path 3 requires aggressive use of production-intent technologies expected to become available within the next 10 years and extensive use of emerging technologies. Specific treatments include:

- multi-valve overhead camshafts in larger vehicles;
- variable valve lift and timing; cylinder deactivation in larger vehicles;
- engine supercharging and downsizing (excludes subcompacts and compacts);
- continuously variable transmissions in most vehicle classes;
- camless valve actuation (E);
- variable compression ratios (E);
- advanced, high torque continuously variable transmissions for some vehicle classes (E);
- 42-volt systems for all vehicle classes (E);
- integrated starter/generator for all vehicle classes (E);
- electric power steering for all vehicle classes(E); and
- vehicle weight reductions for larger sedans and larger SUVs.

EEA Study (27.7 mpg, 2020-2030). Energy and Environmental Analysis, Inc. (EEA) was retained to assess the potential for improved vehicle fuel economy attributes for this report and one of the cases is so identified below. The EEA report author also served as a contractor to the NRC study and incorporated new information from the NRC effort into work performed for the Energy Commission. In the EEA case, specific technology enhancements incorporated to various degrees in each vehicle class include:

- composite aluminum and ultra-high strength steel vehicle bodies;
- electric power steering;
- variable valve timing;
- cylinder deactivation;
- advanced torque converter;
- continuously variable transmissions;
- electrically shifted manual transmissions;
- 42 volt hybrids; and
- on-demand electric four wheel drive.

Higher Vehicle Fuel Economy from Weight Reduction and Associated Safety Implications. An important concern related to achieving higher fuel economy vehicles using weight reduction is the potential impact on vehicle safety. The concern is based on the protective effects of vehicle mass in both single- and multiple-vehicle crashes. All else equal, a heavier vehicle will experience a smaller change in momentum than will a lighter vehicle in a crash (as long as the object that is impacted is moveable), so occupants of the heavier vehicle will undergo less deceleration and therefore be better off. Opponents of using weight reduction to achieve higher fuel economy vehicles have employed this principle to suggest that such increases in vehicle fuel efficiency can increase traffic injuries and fatalities.

However, this principle does not necessarily mean that reducing the weight of most or all new vehicles will reduce safety. Other factors, such as vehicle “crush space” and weight distribution within the fleet also come into play. As an example, reducing only the weight of the heaviest vehicles could actually reduce fatalities, since drivers of smaller autos would be at less risk. In addition, reducing the average weight of all vehicles might improve safety from the point of view of pedestrians and bicyclists.

Empirical studies of the relationship between current CAFE standards and safety have not yielded conclusive results. The previously mentioned 2002 National Research Council study devoted considerable attention to this issue. It found that:

> "… the downsizing and weight reduction that occurred in the late 1970's and early 1980's most likely produced between 1,300 and 2,600 crash fatalities and between 13,000 and 26,000 serious injuries in 1993" (p. 77).

However, two of the 13 committee members (David L. Greene, Maryann Keller) disagreed with this finding and concluded that:

> "the relationships between vehicle weight and safety are complex and not measurable with any reasonable degree of certainty at present" (p. 123).

In addition, a study for Honda that employed more recent data found that:

> "The overall net effect of a 100 pound reduction in passenger vehicle weight on the number of traffic fatalities is small and statistically insignificant" (Executive Summary, p. 2).

This statistical insignificance is a result of two opposing effects, and the study provides an example:

> "… a 100 lb. reduction in passenger car weight: 1) would significantly increase fatalities associated with principal rollovers and collisions with trucks; and 2) would significantly decrease fatalities associated with collisions with other passenger cars, pedestrians, bicycles, and motorcycles" (Executive Summary, p. 3).

Although the impact of past weight reductions on overall safety is not clear, it is still true that reduced vehicle weight and downsizing have the potential to increase traffic injuries and fatalities. Therefore, the effect on safety (if any) of using weight reduction to achieve higher fuel economy standards must be carefully considered.

Methodology

The FUTURES spreadsheet model was used to simulate California light duty vehicle fleet fuel savings and the present worth of consumer out-of-pocket costs or savings for ten different technology packages. Staff calibrated the FUTURES model to the base case gasoline demand projections of the CALCARS model based on the earlier Task 2 work, then used to simulate the impacts of various fuel economy technology packages from the ACEEE and NRC reports and from EEA. The simulations extend out through the year 2030. The results are meant to provide an assessment of the range of what is possible in California.

Technology and cost inputs are based on studies that assume light-duty vehicle fuel economy technologies being implemented at the national level. As a result, costs listed in these reports are based on amortizing capital investments across national vehicle sales. If these same technologies were developed for smaller production volumes (for example, only California's annual sales), the resulting incremental costs to California consumers would be higher than those listed in these studies.

FUTURES Model. The project's consultant, A. D. Little (later, TIAX, LLC), developed a spreadsheet tool to estimate the cost tradeoff between incremental capital cost and fuel savings over a vehicle's life, using advanced energy efficiency technologies in new light-duty vehicle sales.[8] Data from the ACEEE and NRC studies included incremental cost and associated fuel savings. Corresponding per vehicle class data on projected vehicle sales, sales percentages and vehicle miles traveled were obtained from CALCARS (se below)for base case results under future fuel prices of $1.47 per gallon, $1.64 per gallon and $1.81 per gallon. In addition to fuel use, FUTURES provides direct costs and fuel savings benefits to vehicle consumers, but does not account for consumer value of other vehicle attributes such as performance.

CALCARS Model. CALCARS is a vehicle choice model that the CEC uses to forecast future energy demand in the light-duty vehicle sector in California. It is a multinomial logit model that accounts for consumer preference in terms of vehicle attributes, including vehicle price, fuel economy, range, performance and the number of vehicle makes and models available per class. CALCARS applies these consumer preferences to calculate vehicle sales and population by size class, annual vehicle miles traveled, and fuel consumption for California's light-duty fleet. This model was used in the Base Case forecast of gasoline demand in California (Task 2 of this project).

Status

In the Energy Policy and Conservation Act of 1975, the U.S. Congress determined that it was in the national interest to reduce petroleum dependence by establishing Corporate Average Fuel Economy (CAFE) standards. Congress determined that light-duty passenger car fuel economy should improve from 18 miles per gallon in 1978 to 27.5 miles per gallon in 1985. This has remained the CAFE standard. The federal Department of Transportation set similar standards for light trucks, now at 20.7 miles per gallon.

The CAFE program has been controversial since inception. Stakeholders debate the effect of CAFE on fleet average fuel economy, the resultant mix of vehicles consumers operate, safety implications, the health of the U.S. automotive industry, and the well-being of consumers.

Overall new light duty vehicle fuel economy improved from 1978 to 1988, but has since declined due to consumers purchasing increasing quantities of vehicles, including sport utility vehicles, that are built to meet light truck rather than light car CAFE requirements. Light truck sales increased from about 19 percent in 1975 to 28 percent in 1987 and 46 percent in 2000.[9]

Automobile manufacturers have improved vehicle performance while maintaining federal CAFE requirements. For example, since about 1981, manufacturers have improved the horsepower-to-weight ratio about 50 percent and reduced the 0-to-60 miles per hour acceleration by 26 percent. Furthermore, customers have apparently been willing to pay for the cost of these improvements. In 1980 a new car cost about $15,900, while by the year 2000 a new car cost about $22,300.[10]

Correspondingly, fuel economy remained relatively constant while horsepower, weight, horsepower/weight ratio and top speed all increased.[11]

In 2001, Congress asked the National Academy of Sciences to study CAFE requirements, including potential fuel economy improvements and their impact on motor vehicle safety, employment, the automotive business sector, the consumer, and the impact of different CAFE requirements for both domestic and non-domestic vehicle sales. The results of this study were published in a report entitled ***Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards***.

Assumptions

The project's consultant, A.D. Little (Later, TIAX, LLC), developed a spreadsheet tool to estimate the cost tradeoff between incremental capital cost and fuel savings over a vehicle's life, using advanced energy efficiency technologies listed above in new light-duty vehicles.

Fuel Economy Levels. Table 1A-1 shows the level of fuel economy improvement modeled for 13 vehicle classes and each technology evaluated. To accomplish this, it was necessary to associate the five vehicle classes used in the ACEEE study and the ten vehicle classes used in the NAS study with the 13 vehicle classes used in FUTURES. This was accomplished by matching vehicle classes where appropriate. For example, the ACEEE small car results were assumed to apply for the mini car, subcompact and compact vehicle classes for purposes of determining fuel economy improvement and incremental price.[12]

For the FUTURES simulations, fuel efficiency improvements relative to the base case forecast were determined by factoring up the CALCARS baseline estimates using the percent improvements determined in the NRC and ACEEE studies. Due to the complexity of designing and manufacturing automobiles, it was assumed that six years would be needed before new technologies could enter the California market place. In these simulations, during the seven-year implementation period, one seventh of new vehicles in each class were assumed to have the fuel economy listed in Table 1A-1. Deployment was assumed to begin in model year 2008 and proceed uniformly for 7 years, with 100 percent of new vehicle sales occurring by 2014. This allows for a relatively normal turnover rate of vehicle technology, as it usually takes about 7 years for new technologies to saturate new vehicle sales. However, this is not meant to suggest that these market penetrations are going to occur. Rather, they assist in constructing a reasonable bound for what is possible in terms of petroleum reduction, fuel savings and associated economic effects.

For the EEA case, fuel economy improvements, vehicle cost increases, and changes in other attributes relative to the base case were projected directly by EEA. In this case, fuel economy for new vehicles increases more or less gradually (beginning in 2008) over a twelve-year period. The entries in Table 1A-1 for EEA are projections for the model year 2020 to 2030. The EEA baseline values are for the base case for the 2008 model year.

Table 1A-1. On Road and EPA-Rated New Vehicle Fuel Economy Levels for Each Case

Vehicle Class	On-Road Fuel Economy (mpg)								
	EEA Baseline MY 2008	Moderate	Advanced	Mild Hybrid	Full Hybrid	NRC Path 1	NRC Path 2	NRC Path 3	EEA MY 2020-30
Mini Car	38.4	54.6	60.3	70.3	79.2	42.6	46.0	53.9	53.2
Subcompact	29.1	41.4	45.7	53.3	60.0	32.3	34.9	40.8	41.0
Compact	25.6	36.4	40.2	46.8	52.7	28.4	31.1	36.5	34.8
Midsize	22.0	34.3	38.4	44.2	49.7	24.3	29.2	33.5	31.1
Full Size Car	20.2	31.5	35.4	40.6	45.7	22.7	28.1	31.9	27.4
Sports Car	22.7	35.4	39.7	45.5	51.2	25.5	31.5	35.8	26.8
Mini Van	22.1	34.2	40.8	47.9	54.1	25.4	32.6	35.1	29.3
Standard Van	15.1	23.5	28.0	32.8	37.1	17.4	22.4	24.1	19.2
Compact Pickup	19.2	26.4	31.0	35.8	40.4	22.6	28.2	30.4	25.9
Standard Pickup	14.1	19.4	22.8	26.3	29.7	16.2	21.5	22.5	20.6
Mini SUV	23.0	35.0	40.9	48.1	54.1	25.3	30.0	34.8	35.7
Compact SUV	16.8	25.5	29.9	35.1	39.5	20.2	24.6	27.3	22.9
Standard SUV	13.8	21.0	24.6	28.8	32.4	16.6	19.8	22.8	19.9
On-Road Avg. FE	20.4	29.9	34.4	39.9	45.0	23.3	28.0	31.4	27.7
EPA Rated	24.2	35.6	40.9	47.5	53.5	27.7	33.3	37.4	33.0

Table 1A-2 shows the incremental vehicle capital costs for each vehicle class and technology improvement case considered. These costs represent analysts' best estimates of the incremental cost of incorporating each technology in national new car sales. Estimates of incremental costs for state-only implementation would be much higher.[13]

Table 1A-2. Incremental Capital Cost Assumptions for Each Case (Nationwide Deployment, 2001 $)

Vehicle Class	Moderate	Advanced	ACEEE Mild Hybrid	ARB Mild Hybrid	ACEEE Full Hybrid	ARB Full Hybrid	NRC Path 1	NRC Path 2	NRC Path 3	EEA MY 2020-2030
Mini Car	950	1,150	3,200	1,050	4,425	2,325	475	1,025	2,100	822
Subcompact	950	1,150	3,200	1,050	4,425	2,325	475	1,025	2,100	778
Compact	950	1,150	3,200	1,050	4,425	2,325	475	1,075	2,175	841
Midsize	1,050	1,325	3,600	1,250	5,200	2,625	475	1,650	3,250	992
Full Size Car	1,050	1,325	3,600	1,450	5,200	3,150	675	2,175	3,525	943
Sports Car	1,050	1,325	3,600	1,250	5,200	2,625	675	2,175	3,525	480
Mini Van	1,550	2,175	4,250	1,500	5,950	3,300	575	2,225	3,025	737
Standard Van	1,550	2,175	4,250	1,700	5,950	3,800	575	2,225	3,025	693
Compact PU	1,550	2,350	4,650	1,700	6,675	3,800	675	2,225	3,375	599
Standard PU	1,550	2,350	4,650	1,700	6,675	3,800	575	2,550	3,025	611
Mini SUV	1,425	2,150	4,100	1,400	5,600	3,025	475	1,550	2,650	793
Compact SUV	1,425	2,150	4,100	1,400	5,600	3,025	775	2,225	3,650	750
Standard SUV	1,425	2,150	4,100	1,400	5,600	3,025	775	2,075	3,300	790

Table 1A-3 lists the light-duty vehicle classes, current vehicle populations and percentages, as well as the projected new vehicle sales and percentages in 2002 as predicted by CALCARS for the base case. CALCARS determines new vehicle fuel use, vehicle miles traveled and sales distributions in each future modeling year. Future year changes in vehicle distribution and miles traveled were obtained from the CALCARS base case for each fuel price simulated ($1.47, 1.64 and $1.81 per gallon) and used in the FUTURES model.

Table 1A-3. Existing Light-Duty Vehicles and Projected New Vehicle Sales for 2003

	Total 2002 Light-Duty Fleet		**New 2003 Vehicle Sales**	
Class	**Vehicles**	**Fraction (%)**	**Vehicles**	**Fraction (%)**
Mini Car	914,962	4.0	30,739	1.7
Subcompact	3,183,977	13.9	285,065	15.6
Compact	3,765,598	16.4	285,797	15.6
Midsize	3,441,453	15.0	271,182	14.9
Full Size	1,046,000	4.6	73,370	4.0
Sports Car	1,650,610	7.2	78,128	4.3
Compact Truck	1,956,364	8.5	100,267	5.5
Standard Truck	2,282,808	9.9	183,152	10.0
Mini Van	1,551,758	6.8	148,388	8.1
Standard Van	524,149	2.3	27,994	1.5
Mini SUV	96,661	0.4	15,552	0.9
Compact SUV	1,901,749	8.3	260,914	14.3
Standard SUV	672,881	2.9	68,796	3.8
Total	22,988,969	100.0	1,829,688	100.0

In addition to state-specific parameters describing existing and future light-duty vehicles, estimates for vehicle retirement rates were required for the FUTURES simulations. These estimates were obtained from the California Air Resources Board EMFAC model to project vehicle usage and retirement trends over time.[14] These values were adjusted to calibrate the FUTURES output to the CALCARS base case fuel demand predictions for 2003 to 2030. Accounting for lifecycle events, including new vehicle sales, reduced use of a typical vehicle as it ages, and vehicle retirement, enables long-term, fleet-wide trends to be included.

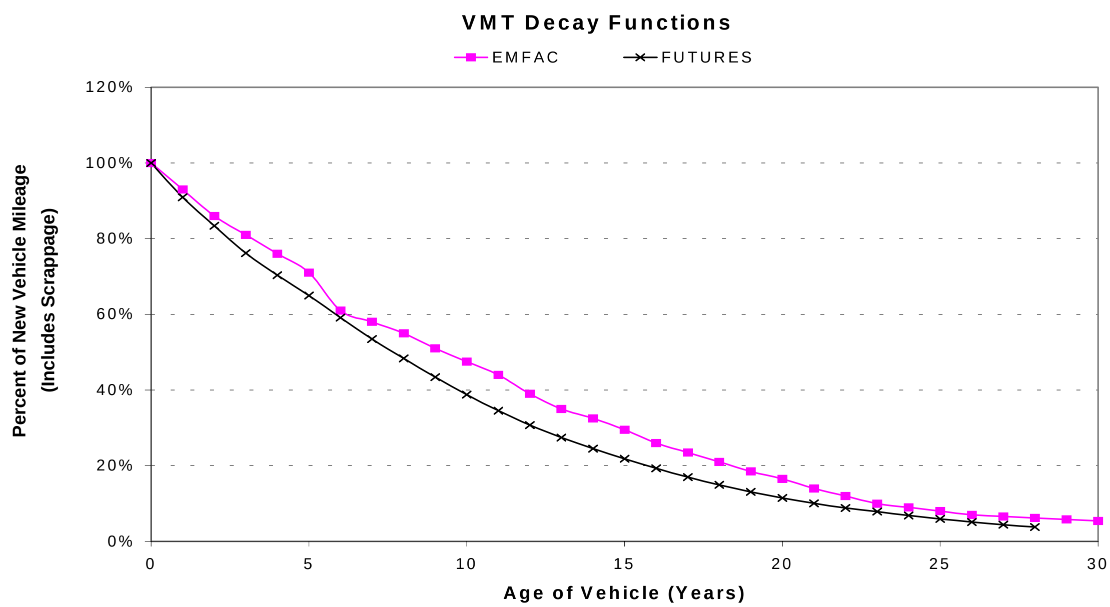
Vehicle Population Dynamics in the FUTURES Simulations. Given the degree of complexity necessary to identify and track long-term vehicle trends noted above, some simplifying assumptions have been made for the FUTURES model. While these simplifications are not strictly accurate, they are consistent with the uncertainties implicit in any long-term forecast. The assumptions and techniques used to model long-term light-duty fleet trends are discussed below.

New technology vehicles are assumed to enter the on road fleet uniformly each model year (MY), with total vehicle sales increasing over time. The sales distributions used in this work are based on base case CALCARS estimates for MY2002 to MY 2030. Slightly different values are needed for each of the three fuel prices simulated. Table 1A-4 summarizes new light-duty

Table 1A-4. Projected New Vehicle Sales Model Years (Input for $1.64 per Gallon)

Vehicle Class	Projected New Vehicle Sales MY 2010	MY 2020	MY 2030
Mini Car	35,349	41,149	47,963
Subcompact	294,158	342,240	397,368
Compact	311,622	368,084	431,379
Midsize	298,366	354,786	418,298
Full Size	92,582	115,669	137,785
Sports Car	80,588	94,844	111,042
Compact Truck	107,521	126,709	143,018
Standard Truck	210,624	249,906	283,710
Mini Van	177,799	215,531	250,862
Standard Van	33,035	39,895	47,963
Mini SUV	21,462	25,091	28,197
Compact SUV	353,284	431,313	491,260
Standard SUV	87,742	103,626	118,309
Total	2,104,132	2,509,093	2,906,865

Figure 1A-1. Vehicle Miles Traveled Over a Model Year's Lifetime



vehicle sales over the span of this analysis, and the distribution of these sales, by class for the mid-value fuel price, $1.64 per gallon.

Annual mileage accumulation for a particular vehicle tends to decrease as the vehicle ages, with transportation demand tracked by total vehicle miles traveled (VMT). VMT over any vehicle population is simply the sum of total mileage accumulated by that population over a given timeframe. This analysis examines VMT for each model year of vehicle sales and tracks it as a given model year ages. For the purposes of this analysis, each model year is assumed to age identically, in terms of VMT decline over time. Figure 1A-1 shows the assumed change in VMT and vehicle population over time. Shown on the chart are the original EMFAC factors and the revised factor used after calibration to CALCARS.

Except for the EEA case, the incremental prices of the more efficient vehicles were held constant from 2008 through 2030, although sales volumes increase over time, which should lead to cost reductions over that same time period.

Advanced Technology Vehicles. Each vehicle class is assumed to have the same rate of new technology sales, regardless of the relative cost effectiveness of the treatment in the vehicle class. The ACEEE moderate and advanced technologies, as well as the three NRC cases, include only conventional gasoline vehicles, while the ACEEE mild and full hybrid cases extend the ACEEE advanced case with two degrees of peak power enhancement. In the EEA case, conventional as well as mild and full hybrid vehicles are assumed to be available, as shown in Table 1A-5. Projected availability for each comes from the EEA analysis.

Table 1A-5. Availability of Vehicles by Class for EEA Simulation

Vehicle Class	Conventional Gasoline	Mild Hybrid	Full Hybrid
Mini Car	✓	✓	✓
Subcompact	✓	✓	✓
Compact	✓	✓	✓
Midsize	✓	✓	
Large Car	✓	✓	
Sports Car	✓		
Compact Pickup	✓	✓	
Standard Pickup	✓	✓	
Minivan	✓	✓	✓
Standard Van	✓		
Mini SUV	✓	✓	✓
Compact SUV	✓	✓	✓
Standard SUV	✓	✓	

Incremental Capital Costs. Each of the cases presented is based upon incremental capital costs associated with nationwide implementation of the associated technologies. A California-only implementation would require substantially higher incremental capital costs.

Fuel Prices. Although staff evaluated a range of prices, in this analysis the fuel price is held constant. If gasoline demand were to drop to the degree shown in Figure 1A-2, oil companies would likely respond by lowering retail fuel prices. This would tend to make the more efficient technologies less cost-effective (simply because the fuel being displaced would cost consumers less).

Results

Results are shown for target years 2020 and 2030. It was not practical to provide results for 2010 because staff assumed the vehicle efficiency improvements would begin in model year 2008, reaching full implementation by 2014. By 2010 there would not be enough advanced technology vehicles to have meaningful results.

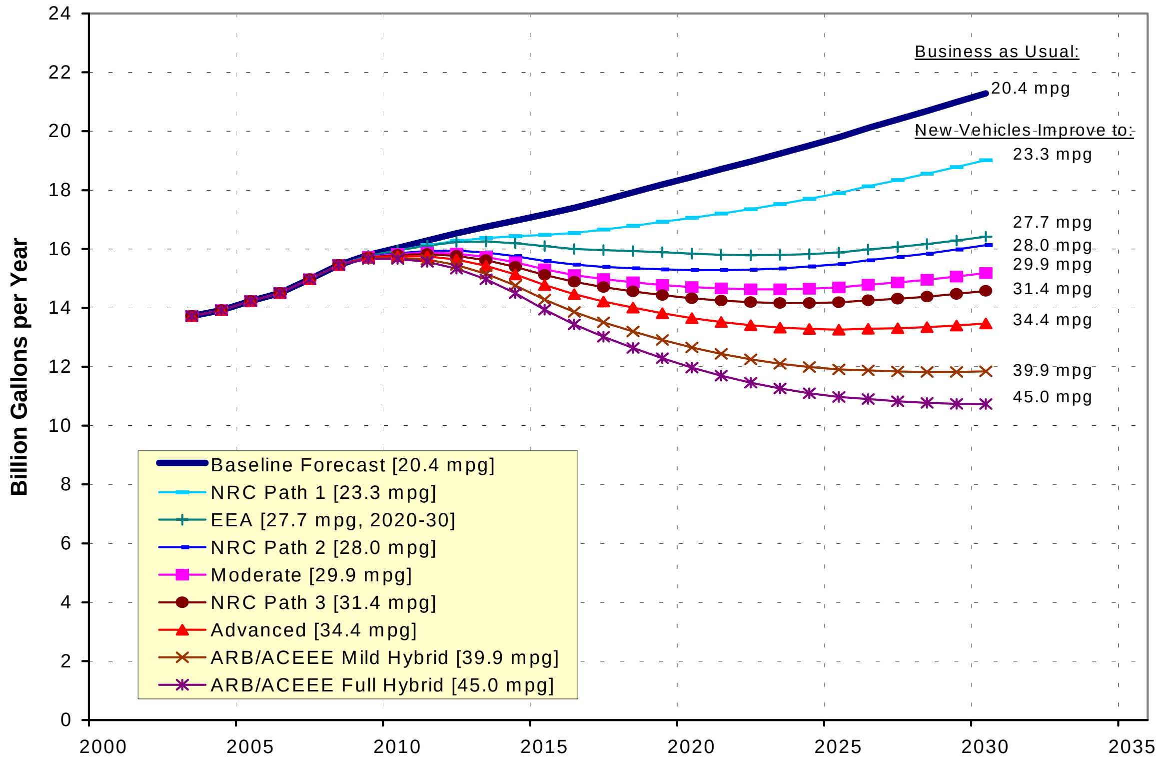
Gasoline Demand Reduction. Gasoline demand reductions for each case are given in Table 1A-6 expressed in terms of millions of gallons of gasoline saved and percent saved relative to the base case forecast for total gasoline demand (not just light-duty vehicles), assuming our median gasoline prices forecast of $1.64 per gallon.[15] Potential fuel savings are bounded by NRC Path 1 on the lower end, displacing 8.1 percent of the otherwise expected gasoline demand in 2030, with the upper bound corresponding to ARB/ACEEE Full Hybrid technology which displaces 50.3 percent of the gasoline demand in 2030.

Table 1A-6. Gasoline Reduction from Improved Vehicle Fuel Economy ($1.64 per gallon)

	2020		2030	
Case	**Annual Reduction (million gallons)**	**Reduction from Base Case (Percent)**	**Annual Reduction (million gallons)**	**Reduction from Base Case (Percent)**
ACEEE Moderate	4,059	21.7	6,282	29.1
ACEEE Advanced	5,195	27.8	8,040	37.2
ACEEE Mild Hybrid	6,275	33.5	9,709	45.0
ARB Mild Hybrid	6,275	33.5	9,709	45.0
ACEEE Full Hybrid	7,017	37.5	10,856	50.3
ARB Full Hybrid	7,017	37.5	10,856	50.3
NRC Path 1	1,512	8.1	2,339	10.8
NRC Path 2	3,428	18.3	5,302	24.6
NRC Path 3	4,462	23.8	6,903	32.0
EEA	2,908	15.5	5,031	23.3

Figure 1A-2 shows projected fuel demand for each case. The more aggressive cases lower gasoline demand nearly to 2002 levels and a few project an even lower gasoline demand than 2002 consumption. However, even in the most aggressive case of the full hybrid vehicle, gasoline demand stops declining and even begins to grow by 2030 as the new technologies saturate the market and vehicle miles traveled continue to grow. All cases except NRC Path 1 accomplish very significant petroleum demand reductions if implemented for California.

Figure 1A-2. Fuel Consumption for Each Case from 2002 to 2030 at $1.64 per Gallon



Direct Economic Benefits of Gasoline Demand Reductions. The increased fuel savings associated with higher fuel economy levels come with higher vehicle costs due to the associated technologies. In many cases, the cost of the new technologies is fully offset by the value of the fuel savings. This is not true, however, for all cases.

Table 1A-7 shows the cumulative benefit to consumers (not including environmental benefits) from 2002 to 2020 and 2030, and their relative rank. Negative values are shown with curved brackets and represent increased costs rather than a benefit. Summed over 2002 to 2020, the ARB Mild Hybrid case provides the best net present value from a consumer perspective. This is followed by the ACEEE Advanced case, then the ACEEE Moderate case, the EEA case and the NRC Path 2 case. Seven of the ten cases provide net consumer benefits. Summed over 2002 to 2030, the ARB Mild Hybrid case again provides the best net present value to consumers, followed by ACEEE Advanced, ACEEE Moderate and the EEA case. Nine of the ten cases provide net consumer benefits over this longer time period.

The change in consumer surplus in most cases is positive; the benefits of reduced fuel consumption outweigh the cumulative effects of higher average vehicle prices. One criticism of measures designed to improve fuel efficiency has been that consumers are more interested in higher vehicle performance than they are in fuel efficiency gains; these results show that consumers are better off with improved fuel economy.[16]

Table 1A-7. Present Value of Consumers Benefits at $1.64 per Gallon (2001$)

Case	2002-2020		2002-2030	
	Million $	Rank	Million $	Rank
ACEEE Moderate	10,781	3	26,738	3
ACEEE Advanced	12,860	2	32,102	2
ACEEE Mild Hybrid	1,829	7	7,887	7
ARB Mild Hybrid	12,975	1	41,239	1
ACEEE Full Hybrid	(6,386)	9	(10,181)	10
ARB Full Hybrid	(8,150)	10	7,072	8
NRC Path 1	3,118	6	7,934	6
NRC Path 2	3,337	5	9,573	5
NRC Path 3	(428)	8	1,683	9
EEA	9,880	4	24,746	4

Table 1A-8. Present Value of Change in Government Revenue at $1.64 per Gallon (Million 2001$)

Case	2002-2020	2002-2030
ACEEE Moderate	(2,228)	(9,813)
ACEEE Advanced	(2,852)	(12,561)
ACEEE Mild Hybrid	(3,445)	(15,171)
ARB Mild Hybrid	(3,445)	(15,171)
ACEEE Full Hybrid	(3,852)	(16,965)
ARB Full Hybrid	(3,852)	(16,965)
NRC Path 1	(829)	(3,654)
NRC Path 2	(1,881)	(8,286)
NRC Path 3	(2,449)	(10,787)
EEA	(1,388)	(6,969)

Table 1A-8 shows the impact of each option on gasoline revenue collected by the government. Government revenue losses include state and federal excise taxes but are offset partially by lower federal ethanol subsidy payments (we subtracted 2.9 cents per gallon, assuming 5.7 percent by volume of ethanol per gallon). Sales tax effects are not included. These losses are proportional to the fuel displacements over the same time periods. The negative entries for government revenues represent the net reduction in gasoline revenues from these two factors due to less gasoline sold relative to the base case forecast.

Table 1A-9 shows the overall net benefit, taking into account the savings (or increased costs) experienced by consumers and the loss of government revenue. The numbers in Table 1A-9 are net of higher vehicle costs, reduced expenditures on fuel, and the loss in government revenue.

Table 1A-9. Present Value of Net Benefits at $1.64 per Gallon (2001$)

Case	2002-2020		2002-2030	
	Million $	Rank	Million $	Rank
ACEEE Moderate	8,553	3	16,925	4
ACEEE Advanced	10,008	1	19,541	2
ACEEE Mild Hybrid	(1,616)	7	(7,284)	7
ARB Mild Hybrid	9,530	2	26,068	1
ACEEE Full Hybrid	(10,238)	9	(27,146)	10
ARB Full Hybrid	(12,002)	10	(9,893)	9
NRC Path 1	2,289	5	4,280	5
NRC Path 2	1,456	6	1,287	6
NRC Path 3	(2,877)	8	(9,104)	8
EEA	8,492	4	17,777	3

Single year results are similar to the present value results shown in Tables 1A-7 through 1A-9. Table 1A-10 summarizes single year consumer benefits (savings or costs), while Table 1A-11 summarizes single year government revenue losses and Table 1A-12 summarizes net costs for each case. Single year results indicate that consumers would be better off with the improved fuel efficiency technologies in eight of the ten cases in 2020 and all ten cases in 2030. As before, the effect on government revenue is proportional to the single year reductions in gasoline demand shown in Table 1A-6.

Table 1A-10. Single Year Consumers Benefits at $1.64 per Gallon (2001$)

Case	2020		2030	
	Million $	Rank	Million $	Rank
ACEEE Moderate	3,555	3	6,227	4
ACEEE Advanced	4,243	2	7,566	3
ACEEE Mild Hybrid	663	7	3,256	6
ARB Mild Hybrid	5,391	1	11,396	1
ACEEE Full Hybrid	(2,005)	10	26	10
ARB Full Hybrid	250	8	7,942	2
NRC Path 1	1,033	6	1,930	8
NRC Path 2	1,123	5	2,778	7
NRC Path 3	(94)	9	1,555	9
EEA	3,417	4	5,687	5

Table 1A-11. Single Year Change in Government Revenue at $1.64 per Gallon (2001$)

Case	2020	2030
ACEEE Moderate	(1,356)	(2,098)
ACEEE Advanced	(1,735)	(2,685)
ACEEE Mild Hybrid	(2,096)	(3,243)
ARB Mild Hybrid	(2,096)	(3,243)
ACEEE Full Hybrid	(2,344)	(3,626)
ARB Full Hybrid	(2,344)	(3,626)
NRC Path 1	(505)	(781)
NRC Path 2	(1,145)	(1,771)
NRC Path 3	(1,490)	(2,305)
EEA	(971)	(1,680)

Table 1A-12. Single Year Net Savings at $1.64 per Gallon (2001$)

	2020		2030	
Case	Million $	Rank	Million $	Rank
ACEEE Moderate	2,199	4	4,129	4
ACEEE Advanced	2,508	2	4,881	2
ACEEE Mild Hybrid	(1,433)	7	13	8
ARB Mild Hybrid	3,295	1	8,153	1
ACEEE Full Hybrid	(4,349)	10	(3,600)	10
ARB Full Hybrid	(2,094)	9	4,316	3
NRC Path 1	528	5	1,149	6
NRC Path 2	(22)	6	1,007	7
NRC Path 3	(1,584)	8	(750)	9
EEA	2,445	3	4,007	5

As in the present value results summed over the two intervals, the single year results vary depending upon the degree to which advanced technologies are deployed and their expected costs. Results are shown with curved brackets when costs increase or government revenue is reduced. Once again, the ARB Mild Hybrid, ACEEE Moderate, and ACEEE Advanced cases are the most attractive, with the relative ranking varying somewhat depending upon the consumer or the net perspective and the time period considered. The ARB Full Hybrid case is also very attractive in 2030.

To determine the relative cost effectiveness of the cases, taking into consideration the amount of fuel displaced as well as the dollars saved or expended, we divide the single year savings (or costs) by the corresponding gallons of gasoline saved in the same year. This scaling of the savings (or costs) by the gallons saved gives a metric that can be used to evaluate the relative cost effectiveness of each case. These results are shown in Table 1A-13 for consumer benefits.

Table 1A-13. Consumers Dollars per Gallon Saved at a Fuel Cost of $1.64 per Gallon (2001$)

Case	2020		2030	
	Million $	**Rank**	**Million $**	**Rank**
ACEEE Moderate	0.88	2	0.99	3
ACEEE Advanced	0.82	4	0.94	4
ACEEE Mild Hybrid	0.11	7	0.34	8
ARB Mild Hybrid	0.86	3	1.17	1
ACEEE Full Hybrid	(0.29)	10	0.00	10
ARB Full Hybrid	0.04	8	0.73	6
NRC Path 1	0.68	5	0.83	5
NRC Path 2	0.33	6	0.52	7
NRC Path 3	(0.02)	9	0.23	9
EEA	1.17	1	1.13	2

Table 1A-14. Net Dollars per Gallon Saved at A Fuel Cost of $1.64 per Gallon (2001$)

Case	2020		2030	
	Million $	**Rank**	**Million $**	**Rank**
ACEEE Moderate	0.54	2	0.66	3
ACEEE Advanced	0.48	4	0.61	4
ACEEE Mild Hybrid	(0.23)	7	0.00	8
ARB Mild Hybrid	0.53	3	0.84	1
ACEEE Full Hybrid	(0.62)	10	(0.33)	10
ARB Full Hybrid	(0.30)	8	0.40	6
NRC Path 1	0.35	5	0.49	5
NRC Path 2	(0.01)	6	0.19	7
NRC Path 3	(0.36)	9	(0.11)	9
EEA	0.84	1	0.80	2

(savings or costs) and in Table 1A-14 for net revenue. Government revenue lost is not shown because it is a uniform $0.334 per gallon displaced.

When the benefits are scaled by the amount of fuel saved and the results are expressed in terms of dollars saved per gallon displaced, a somewhat different relative ranking pattern emerges. The EEA option is the most cost effective from both a consumer perspective and for net benefits in 2020 while the ARB Mild Hybrid case is the most cost effective in 2030 and the EEA case is second most cost effective. The ACEEE Moderate case is second in 2020 and third in 2030. The ACEEE Advanced case ranks fourth, followed by the NRC Path 1 case, fifth.

Key Drivers and Uncertainties

Several variables interact to impact the results for each case. Changes in these variables, such as fuel price or technology cost, can dramatically alter the relative rankings.

Gasoline Fuel Price. Future gasoline prices have a greater effect on the results than any other variable considered in this study. Consistent with the CEC's projections of fuel prices for this study, the cases reported above assume a constant fuel price of $1.64 per gallon of gasoline from 2008 to 2030. Sensitivity analyses were performed using gasoline prices with a low value of $1.47 per gallon and a high value of $1.81 per gallon, representing a cost range of minus and plus one standard deviation.

The CALCARS model was run for base case conditions at $1.47 per gallon and $1.81 per gallon to obtain VMT and percent sales by vehicle class based upon consumer vehicle choices at these fuel prices. These values were input into the FUTURES model to evaluate the cost effectiveness of each case at these two alternative fuel prices.

The corresponding results for the FUTURES sensitivity runs are listed in Tables 1A-15 through 1A-18 for the $1.47 per gallon results and Tables 1A-19 through 1A-22 for the $1.81 per gallon results.

Gasoline demand reductions estimated at a fuel price of $1.47 per gallon (see Table 1A-15) are very similar to the results at $1.64 per gallon (see Table 1A-6). Somewhat less gasoline is saved at a fuel price of $1.47 per gallon than at $1.64 per gallon. This results because consumers tend to purchase less fuel efficient vehicles at lower fuel prices and more fuel efficient vehicles at higher fuel prices.

From the consumer's perspective, if the lower fuel price of $1.47 per gallon best represents future gasoline prices, the most cost effective cases are the ACEEE Advanced, ARB Mild Hybrid ACEEE Moderate, EEA, and NRC Path 1 cases. Consistent with fuel displacement, fewer cases result in consumer benefits at the lower fuel price of $1.47 per gallon. Five of these cases provide consumer benefits over the 2002 to 2020 time period and six over the 2002 to 2030 time period.

Gasoline demand reductions estimated at a fuel price of $1.81 per gallon also are consistent with previous results. As stated above, more gasoline is saved at a fuel price of $1.81 per gallon than at $1.64 per gallon or $1.47 per gallon. In addition, if the higher fuel price of $1.81 best represents future gasoline prices, the economic results are very supportive of improved fuel economy technologies for nearly all cases considered.

From the consumer perspective, all but the ACEEE Full Hybrid and ARB Full Hybrid cases are cost effective for the 2002 to 2020 time period and results are even more positive when extended to 2030, when all ten cases are cost effective. The relative ranking of the most cost-effective cases does vary. When the government revenue losses are included (see net results, Table 1A-22), net results are positive for all but two cases by 2020 and 2030.

Table 1A-15. Gasoline Demand Reductions from FUTURES Simulations at $1.47 per Gallon

Case	2020		2030	
	Annual Reduction (million gallons)	Reduction from Base Case (Percent)	Annual Reduction (million gallons)	Reduction from Base Case (Percent)
ACEEE Moderate	3,870	19.8	6,058	27.0
ACEEE Advanced	5,026	25.7	7,846	35.0
ACEEE Mild Hybrid	6,121	31.4	9,540	42.6
ARB Mild Hybrid	6,121	31.4	9,540	42.6
ACEEE Full Hybrid	6,874	35.2	10,704	47.8
ARB Full Hybrid	6,874	35.2	10,704	47.8
NRC Path 1	1,288	6.6	2,060	9.2
NRC Path 2	3,238	16.6	5,076	22.7
NRC Path 3	4,284	21.9	6,695	29.9
EEA	2,681	13.7	4,780	21.3

Table 1A-16. Present Value of Consumers Benefits at $1.47 per Gallon (2001$)

Case	2002-2020		2002-2030	
	Million $	Rank	Million $	Rank
ACEEE Moderate	6,964	3	19,029	3
ACEEE Advanced	8,502	1	23,115	2
ACEEE Mild Hybrid	(3,053)	7	(2,345)	7
ARB Mild Hybrid	8,176	2	31,189	1
ACEEE Full Hybrid	(11,640)	9	(21,299)	10
ARB Full Hybrid	(13,220)	10	(3,698)	8
NRC Path 1	350	5	2,726	5
NRC Path 2	(371)	6	2,148	6
NRC Path 3	(4,628)	8	(6,914)	9
EEA	6,655	4	18,146	4

Table 1A-17. Present Value of Change in Government Revenue at $1.47 per Gallon (Million 2001$)

Case	2002-2020	2002-2030
ACEEE Moderate	(2,020)	(9,207)
ACEEE Advanced	(2,655)	(12,001)
ACEEE Mild Hybrid	(3,256)	(14,650)
ARB Mild Hybrid	(3,256)	(14,650)
ACEEE Full Hybrid	(3,670)	(16,470)
ARB Full Hybrid	(3,670)	(16,470)
NRC Path 1	(603)	(2,964)
NRC Path 2	(1,673)	(7,677)
NRC Path 3	(2,248)	(10,206)
EEA	(1,155)	(6,282)

Table 1A-18. Present Value of Net Savings at $1.47 per Gallon (2001$)

Case	2002-2020		2002-2030	
	Million $	Rank	Million $	Rank
ACEEE Moderate	4,944	3	9,822	4
ACEEE Advanced	5,847	1	11,114	3
ACEEE Mild Hybrid	(6,309)	7	(16,995)	7
ARB Mild Hybrid	4,920	4	16,539	1
ACEEE Full Hybrid	(15,310)	9	(37,769)	10
ARB Full Hybrid	(16,890)	10	(20,168)	9
NRC Path 1	(253)	5	(238)	5
NRC Path 2	(2,044)	6	(5,529)	6
NRC Path 3	(6,876)	8	(17,120)	8
EEA	5,500	2	11,864	2

Table 1A-19. Gasoline Demand Reductions from FUTURES Simulations at $1.81 per Gallon

Case	2020		2030	
	Annual Reduction (million gallons)	Reduction from Base Case (Percent)	Annual Reduction (million gallons)	Reduction from Base Case (Percent)
ACEEE Moderate	4,240	21.7	6,501	29.0
ACEEE Advanced	5,358	27.4	8,229	36.7
ACEEE Mild Hybrid	6,422	32.9	9,873	44.1
ARB Mild Hybrid	6,422	32.9	9,873	44.1
ACEEE Full Hybrid	7,153	36.6	11,004	49.1
ARB Full Hybrid	7,153	36.6	11,004	49.1
NRC Path 1	1,726	8.8	2,610	11.6
NRC Path 2	3,610	18.5	5,523	24.6
NRC Path 3	4,633	23.7	7,105	31.7
EEA	3,100	15.9	5,265	23.5

Table 1A-20. Present Value of Consumers Benefits at $1.81 per Gallon (2001$)

Case	2002-2020		2002-2030	
	Million $	Rank	Million $	Rank
ACEEE Moderate	14,911	3	34,967	3
ACEEE Advanced	17,540	2	41,630	2
ACEEE Mild Hybrid	6,956	6	18,483	6
ARB Mild Hybrid	18,093	1	51,778	1
ACEEE Full Hybrid	(877)	9	1,318	10
ARB Full Hybrid	(2,631)	10	18,521	5
NRC Path 1	5,997	7	13,207	8
NRC Path 2	7,004	5	16,722	7
NRC Path 3	3,730	8	9,997	9
EEA	13,590	4	31,947	4

Table 1A-21. Present Value of Change in Government Revenue at $1.81 per Gallon (Million 2001$)

Case	2002-2020	2002-2030
ACEEE Moderate	(2,426)	(10,396)
ACEEE Advanced	(3,040)	(13,099)
ACEEE Mild Hybrid	(3,624)	(15,670)
ARB Mild Hybrid	(3,624)	(15,670)
ACEEE Full Hybrid	(4,026)	(17,439)
ARB Full Hybrid	(4,026)	(17,439)
NRC Path 1	(1,046)	(4,318)
NRC Path 2	(2,080)	(8,872)
NRC Path 3	(2,642)	(11,344)
EEA	(1,625)	(7,639)

Table 1A-22. Present Value of Net Benefits at $1.81 per Gallon (Million 2001$)

Case	2002-2020		2002-2030	
	Million $	Rank	Million $	Rank
ACEEE Moderate	12,485	3	24,571	3
ACEEE Advanced	14,500	1	28,531	2
ACEEE Mild Hybrid	3,332	7	2,813	7
ARB Mild Hybrid	14,469	2	36,108	1
ACEEE Full Hybrid	(4,903)	9	(16,121)	10
ARB Full Hybrid	(6,657)	10	1,083	8
NRC Path 1	4,951	5	8,889	5
NRC Path 2	4,924	6	7,850	6
NRC Path 3	1,088	8	(1,347)	9
EEA	11,965	4	24,308	4

Technology Cost Estimates. The technology costs used in this work are based on estimates derived by the NRC, ACEEE, ARB and EEA. Each of these estimates represents careful, thoughtful analysis. However, the long-term nature of these forecasts results in a significant degree of uncertainty in the technology costs used in this examination. The economic impacts calculated in this effort are, not surprisingly, highly dependent upon the assumed cost of improved fuel economy. NRC and ACEEE incremental capital costs were adjusted to 2001 dollars and then rounded to the nearest $25.

The studies were consulted to minimize this uncertainty by examining a range of costs. This effort presents this range as an attempt to bracket potential costs and benefits. It is likely that the actual range of technology costs is narrower than those presented here, as industry innovation is difficult to predict. This is especially true for the most advanced fuel efficiency technologies like full hybrids since cost estimates for this technology are "best guesses" today. The implications of these shifts in technology cost, however, are obvious. Lower technology costs not only mean higher "net" benefits, but they also lead to broader technology use and introduction.

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[1] "Technical Options for Improving the Fuel Economy of U.S. Cars and Light Trucks by 2010-2105", ACEEE, April 2001.

[2] "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards", Committee on the Effectiveness and Impact of Corporate Average Fuel Economy (CAFÉ) Standards, National Research Council (NRC), National Academy Press.

[3] "Analysis and Forecast of the Performance and Cost of Conventional and Electric Hybrid Vehicles", Energy and Environmental Analysis, Inc., February 2002 (Final Report).

[4] Numerical values in brackets are computed by FUTURES. They should be compared to "Business as Usual" at 20.4 mpg.

[5] Near-term hybrids now being introduced by automobile manufacturers are more likely to use technologies from the moderate treatment (see text for an exception for the Honda Insight).

[6] Production-intent technologies are well known to manufacturers and could be quickly incorporated into vehicles once a decision is made to use them. Some are already available.

[7] Emerging technologies are generally beyond the research phase and are fundamentally sound, but need more development before they could be incorporated into vehicles. They should be available within 10 to 15 years.

[8] Data from the ACEEE, ARB and NRC studies were used for incremental vehicle cost and associated fuel savings. Corresponding per vehicle class data on projected vehicle sales, sales percentages and vehicle miles traveled were obtained from CALCARS for base case results under future fuel prices of $1.47 per gallon, $1.64 per gallon and $1.81 per gallon. In addition to fuel use, FUTURES provides direct costs and fuel savings benefits to vehicle consumers, but does not account for consumer value of other vehicle attributes such as performance.

[9] Data from Reference 1.

[10] NRC, Figure 2-8, adjusted to $2001 dollars.

[11] NRC, Figure 2-7.

[12] The numbers in each class for 2002, the base year used in CALCARS, come from California Department of Motor Vehicles registration data. The baseline fuel economy values in this table are predicted by EEA for 2002.

[13] In general, capital costs were obtained directly from the two references, adjusting to year 2001 dollars, and rounding to the nearest $25. These values were applied to the 13 vehicle classes in the same manner as the fuel economy values. One variation is that the ACEEE Mild Hybrid and ACEEE Full Hybrid cases were supplemented with lower cost data based upon ARB staff estimates for price reductions that could occur due to market growth that reduces battery costs and assuming a major breakthrough in electric motor and controller costs. Moderate cost reductions are assumed for the 2010 to 2015 time period, while much more aggressive cost reductions are assumed for the 2016 to 2030 time period.. These ARB values were not rounded to the nearest $25. These cases are called "ARB Mild Hybrid" and "ARB Full Hybrid"cases. The fuel economy was the same as corresponding ACEEE cases.

[14] EMFAC is an engineering model employed by ARB to track vehicle use and emissions. For further information on the EMFAC model, see California Air Resources Board Staff Report, "Public Meeting to Consider Approval of Revisions to the State's On-Road Motor Vehicle Emissions Inventory," May 2000. Or consult ARB's Website at http://www.arb.ca.gov/msei/msei.htm.

[15] Total gasoline demand includes gasoline demand for light-duty vehicles and heavier vehicles, mainly medium-duty vehicles. Light-duty gasoline demand is estimated at 13.7 billion gallons by 2003 and the total gasoline demand is estimated at 14.7 billion gallons by 2003.

[16] There may well be effects not captured here; for example, vehicle weight reductions. In providing a revised set of vehicle attributes for this analysis, EEA assumed that higher fuel economy requirements induce manufacturers to reduce slightly the weight of some models to improve fuel efficiency. Therefore, to the extent vehicle owners value weight as an attribute, the estimated net benefits of higher fuel economy may be overstated in the EEA case. The NRC and ACEEE reports indicate that vehicle weight is either maintained, or slightly increased to allow for increased use of safety features. As another example of an omitted effect, manufacturer efforts to improve fuel economy may involve the use of composite materials that can potentially prolong the life of a vehicle.

Table 1A-23

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: ACEEE Moderate

Fuel Price: $1.47

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$6,963	($2,020)	$4,943
2002 to 2030	$19,028	($9,206)	$9,822

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$2,580	($1,292)	$1,288
2030	$4,821	($2,023)	$2,797

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	22,899	2020	3,869	19.8%
2002 to 2030	74,672	2030	6,058	27.0%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.67	($0.33)	$0.33
2030	$0.80	($0.33)	$0.46

Table 1A-24

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: ACEEE Moderate
Fuel Price: $1.64

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$10,697	($2,219)	$8,478
2002 to 2030	$26,644	($9,795)	$16,849

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$3,549	($1,354)	$2,194
2030	$6,226	($2,098)	$4,128

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	24,902	2020	4,055	21.7%
2002 to 2030	78,739	2030	6,281	29.1%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.88	($0.33)	$0.54
2030	$0.99	($0.33)	$0.66

Table 1A-25

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: ACEEE Moderate

Fuel Price: $1.81

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$14,910	($2,426)	$12,484
2002 to 2030	$34,964	($10,395)	$24,569

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$4,583	($1,416)	$3,167
2030	$7,707	($2,171)	$5,536

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	26,982	2020	4,239	21.7%
2002 to 2030	82,854	2030	6,501	29.0%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$1.08	($0.33)	$0.75
2030	$1.19	($0.33)	$0.85

Table 1A-26

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: ACEEE Advanced

Fuel Price: $1.47

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$8,502	($2,655)	$5,847
2002 to 2030	$23,113	($12,001)	$11,112

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$3,092	($1,678)	$1,413
2030	$5,888	($2,620)	$3,267

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	30,016	2020	5,025	25.7%
2002 to 2030	97,124	2030	7,846	35.0%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.62	($0.33)	$0.28
2030	$0.75	($0.33)	$0.42

Table 1A-27

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: ACEEE Advanced

Fuel Price: $1.64

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$12,859	($2,852)	$10,007
2002 to 2030	$32,101	($12,561)	$19,540

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$4,242	($1,735)	$2,507
2030	$7,566	($2,685)	$4,881

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	31,985	2020	5,195	27.8%
2002 to 2030	100,919	2030	8,040	37.2%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.82	($0.33)	$0.48
2030	$0.94	($0.33)	$0.61

Table 1A-28

Summary of Analysis Results

Option 1A: Improved Vehicle Fuel Economy

Case: ACEEE Advanced

Fuel Price: $1.81

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$17,539	($3,040)	$14,499
2002 to 2030	$41,628	($13,099)	$28,529

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$5,452	($1,789)	$3,662
2030	$9,319	($2,748)	$6,571

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	33,868	2020	5,358	27.4%
2002 to 2030	104,570	2030	8,229	36.7%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$1.02	($0.33)	$0.68
2030	$1.13	($0.33)	$0.80

Table 1A-29

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: ACEEE Mild Hybrid

Fuel Price: $1.47

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	($3,054)	($3,256)	($6,310)
2002 to 2030	($2,347)	($14,649)	($16,996)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($661)	($2,044)	($2,706)
2030	$1,313	($3,186)	($1,874)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	36,762	2020	6,121	31.4%
2002 to 2030	118,400	2030	9,540	42.6%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($0.11)	($0.33)	($0.44)
2030	$0.14	($0.33)	($0.20)

Table 1A-30

Summary of Analysis Results

Option 1A: Improved Vehicle Fuel Economy

Case: ACEEE Mild Hybrid

Fuel Price: $1.64

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$1,828	($3,445)	($1,617)
2002 to 2030	$7,885	($15,170)	($7,285)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$662	($2,096)	($1,434)
2030	$3,256	($3,243)	$13

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	38,632	2020	6,274	33.5%
2002 to 2030	121,880	2030	9,709	45.0%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.11	($0.33)	($0.23)
2030	$0.34	($0.33)	$0.00

Table 1A-31

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: ACEEE Mild Hybrid
Fuel Price: $1.81

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$6,955	($3,624)	$3,331
2002 to 2030	$18,481	($15,670)	$2,811

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$2,018	($2,145)	($127)
2030	$5,241	($3,298)	$1,944

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	40,419	2020	6,421	32.9%
2002 to 2030	125,227	2030	9,873	44.1%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.31	($0.33)	($0.02)
2030	$0.53	($0.33)	$0.20

Table 1A-32

Summary of Analysis Results

Option 1A: Improved Vehicle Fuel Economy

Case: ARB Mild Hybrid

Fuel Price: $1.47

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$8,176	($3,256)	$4,920
2002 to 2030	$31,188	($14,649)	$16,539

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$4,097	($2,044)	$2,053
2030	$9,481	($3,186)	$6,294

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	36,762	2020	6,121	31.4%
2002 to 2030	118,400	2030	9,540	42.6%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.67	($0.33)	$0.34
2030	$0.99	($0.33)	$0.66

Table 1A-33

Summary of Analysis Results

Option 1A: Improved Vehicle Fuel Economy

Case: ARB Mild Hybrid

Fuel Price: $1.64

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$12,974	($3,445)	$9,529
2002 to 2030	$41,237	($15,170)	$26,067

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$5,390	($2,096)	$3,295
2030	$11,396	($3,243)	$8,153

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	38,632	2020	6,274	33.5%
2002 to 2030	121,881	2030	9,709	45.0%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.86	($0.33)	$0.53
2030	$1.17	($0.33)	$0.84

Table 1A-34

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: ARB Mild Hybrid

Fuel Price: $1.81

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$18,092	($3,624)	$14,468
2002 to 2030	$51,776	($15,670)	$36,106

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$6,739	($2,145)	$4,594
2030	$13,361	($3,298)	$10,064

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	40,419	2020	6,421	32.9%
2002 to 2030	125,227	2030	9,873	44.1%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$1.05	($0.33)	$0.72
2030	$1.35	($0.33)	$1.02

Table 1A-35

Summary of Analysis Results

Option 1A: Improved Vehicle Fuel Economy

Case: ACEEE Full Hybrid

Fuel Price: $1.47

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	($11,640)	($3,670)	($15,310)
2002 to 2030	($21,300)	($16,469)	($37,769)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($3,452)	($2,296)	($5,748)
2030	($2,106)	($3,575)	($5,681)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	41,398	2020	6,874	35.2%
2002 to 2030	133,022	2030	10,704	47.8%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($0.50)	($0.33)	($0.84)
2030	($0.20)	($0.33)	($0.53)

Table 1A-36

Summary of Analysis Results

Option 1A: Improved Vehicle Fuel Economy

Case: ACEEE Full Hybrid

Fuel Price: $1.64

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	($6,386)	($3,852)	($10,238)
2002 to 2030	($10,182)	($16,964)	($27,146)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($2,006)	($2,343)	($4,349)
2030	$26	($3,626)	($3,600)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	43,202	2020	7,016	37.5%
2002 to 2030	136,292	2030	10,856	50.3%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($0.29)	($0.33)	($0.62)
2030	$0.00	($0.33)	($0.33)

Table 1A-37

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: ACEEE Full Hybrid

Fuel Price: $1.81

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	($878)	($4,026)	($4,904)
2002 to 2030	$1,317	($17,438)	($16,121)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($525)	($2,389)	($2,914)
2030	$2,203	($3,675)	($1,473)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	44,925	2020	7,153	36.6%
2002 to 2030	139,432	2030	11,004	49.1%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($0.07)	($0.33)	($0.41)
2030	$0.20	($0.33)	($0.13)

Table 1A-38

Summary of Analysis Results

Option 1A: Improved Vehicle Fuel Economy

Case: ARB Full Hybrid

Fuel Price: $1.47

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	($13,220)	($3,670)	($16,890)
2002 to 2030	($3,700)	($16,469)	($20,169)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($1,132)	($2,296)	($3,428)
2030	$5,836	($3,575)	$2,261

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	41,398	2020	6,874	35.2%
2002 to 2030	133,022	2030	10,704	47.8%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($0.16)	($0.33)	($0.50)
2030	$0.55	($0.33)	$0.21

Table 1A-39

Summary of Analysis Results

Option 1A: Improved Vehicle Fuel Economy

Case: ARB Full Hybrid

Fuel Price: $1.64

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	($8,151)	($3,852)	($12,003)
2002 to 2030	$7,071	($16,964)	($9,893)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$249	($2,343)	($2,095)
2030	$7,942	($3,626)	$4,316

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	43,202	2020	7,016	37.5%
2002 to 2030	136,292	2030	10,856	50.3%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.04	($0.33)	($0.30)
2030	$0.73	($0.33)	$0.40

Table 1A-40

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: ARB Full Hybrid

Fuel Price: $1.81

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	($2,632)	($4,026)	($6,658)
2002 to 2030	$18,520	($17,438)	$1,082

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$1,725	($2,389)	($664)
2030	$10,092	($3,675)	$6,416

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	44,924	2020	7,153	36.6%
2002 to 2030	139,429	2030	11,004	49.1%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.24	($0.33)	($0.09)
2030	$0.92	($0.33)	$0.58

Table 1A-41

Summary of Analysis Results

Option 1A: Improved Vehicle Fuel Economy

Case: NRC Path 1

Fuel Price: $1.47

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$349	($603)	($254)
2002 to 2030	$2,723	($2,963)	($240)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$402	($430)	($28)
2030	$1,064	($688)	$376

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	7,002	2020	1,287	6.6%
2002 to 2030	24,511	2030	2,061	9.2%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.31	($0.33)	($0.02)
2030	$0.52	($0.33)	$0.18

Table 1A-42

Summary of Analysis Results

Option 1A: Improved Vehicle Fuel Economy

Case: NRC Path 1

Fuel Price: $1.64

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$3,117	($829)	$2,288
2002 to 2030	$7,931	($3,653)	$4,278

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$1,031	($505)	$527
2030	$1,930	($781)	$1,149

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	9,300	2020	1,511	8.1%
2002 to 2030	29,354	2030	2,339	10.8%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.68	($0.33)	$0.35
2030	$0.83	($0.33)	$0.49

Table 1A-43

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: NRC Path 1

Fuel Price: $1.81

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$5,995	($1,046)	$4,949
2002 to 2030	$13,205	($4,317)	$8,888

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$1,650	($576)	$1,074
2030	$2,785	($872)	$1,913

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	11,501	2020	1,725	8.8%
2002 to 2030	34,021	2030	2,610	11.6%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.96	($0.33)	$0.62
2030	$1.07	($0.33)	$0.73

Table 1A-44

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: NRC Path 2

Fuel Price: $1.47

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	($371)	($1,673)	($2,044)
2002 to 2030	$2,146	($7,676)	($5,530)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$184	($1,081)	($897)
2030	$1,444	($1,695)	($252)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	19,001	2020	3,237	16.6%
2002 to 2030	62,378	2030	5,076	22.7%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.06	($0.33)	($0.28)
2030	$0.28	($0.33)	($0.05)

Table 1A-45

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: NRC Path 2

Fuel Price: $1.64

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$3,336	($1,881)	$1,455
2002 to 2030	$9,571	($8,286)	$1,285

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$1,122	($1,145)	($23)
2030	$2,778	($1,771)	$1,007

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	21,095	2020	3,427	18.3%
2002 to 2030	66,572	2030	5,302	24.6%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.33	($0.33)	($0.01)
2030	$0.52	($0.33)	$0.19

Table 1A-46

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: NRC Path 2
Fuel Price: $1.81

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$7,002	($2,080)	$4,922
2002 to 2030	$16,720	($8,872)	$7,848

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$1,999	($1,206)	$793
2030	$4,036	($1,845)	$2,191

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	23,099	2020	3,610	18.5%
2002 to 2030	70,610	2030	5,523	24.6%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.55	($0.33)	$0.22
2030	$0.73	($0.33)	$0.40

Table 1A-47

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: NRC Path 3

Fuel Price: $1.47

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	($4,629)	($2,247)	($6,876)
2002 to 2030	($6,916)	($10,206)	($17,122)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($1,194)	($1,431)	($2,625)
2030	($30)	($2,236)	($2,266)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	25,447	2020	4,283	21.9%
2002 to 2030	82,701	2030	6,695	29.9%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($0.28)	($0.33)	($0.61)
2030	($0.00)	($0.33)	($0.34)

Table 1A-48

Summary of Analysis Results

Option 1A: Improved Vehicle Fuel Economy

Case: NRC Path 3

Fuel Price: $1.64

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	($429)	($2,449)	($2,878)
2002 to 2030	$1,682	($10,786)	($9,104)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($95)	($1,490)	($1,585)
2030	$1,555	($2,305)	($750)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	27,467	2020	4,461	23.8%
2002 to 2030	86,659	2030	6,903	32.0%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	($0.02)	($0.33)	($0.36)
2030	$0.23	($0.33)	($0.11)

Table 1A-49

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: NRC Path 3

Fuel Price: $1.81

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$3,729	($2,642)	$1,087
2002 to 2030	$9,995	($11,343)	($1,348)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$944	($1,547)	($603)
2030	$3,062	($2,373)	$689

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	29,399	2020	4,632	23.7%
2002 to 2030	90,468	2030	7,105	31.7%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.20	($0.33)	($0.13)
2030	$0.43	($0.33)	$0.10

Table 1A-50

Summary of Analysis Results
Option 1A: Improved Vehicle Fuel Economy

Case: EEA

Fuel Price: $1.47

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$6,654	($1,155)	$5,499
2002 to 2030	$18,144	($6,281)	$11,863

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$2,584	($895)	$1,688
2030	$4,458	($1,597)	$2,861

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	13,473	2020	2,681	13.7%
2002 to 2030	52,901	2030	4,780	21.3%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$0.96	($0.33)	$0.63
2030	$0.93	($0.33)	$0.60

Table 1A-51

Summary of Analysis Results

Option 1A: Improved Vehicle Fuel Economy

Case: EEA

Fuel Price: $1.64

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$9,879	($1,388)	$8,491
2002 to 2030	$24,743	($6,969)	$17,774

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$3,415	($971)	$2,444
2030	$5,687	($1,680)	$4,007

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	15,847	2020	2,908	15.5%
2002 to 2030	57,665	2030	5,031	23.3%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$1.17	($0.33)	$0.84
2030	$1.13	($0.33)	$0.80

Table 1A-52

Summary of Analysis Results

Option 1A: Improved Vehicle Fuel Economy

Case: EEA

Fuel Price: $1.81

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2020	$13,589	($1,625)	$11,964
2002 to 2030	$31,945	($7,638)	$24,307

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$4,260	($1,035)	$3,225
2030	$6,973	($1,759)	$5,214

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2020	18,192	2020	3,099	15.9%
2002 to 2030	62,163	2030	5,265	23.5%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2020	$1.37	($0.33)	$1.04
2030	$1.32	($0.33)	$0.99

Staff Paper on Option 1B
Fuel-Efficient Replacement Tires and Tire Inflation

Description

This option evaluates possible reductions in fuel consumption through greater use of low-rolling resistance (LRR) replacement tires and through better monitoring of tire inflation pressures. This result would be achieved through an education program on 1) energy efficiency performance of tires and 2) the benefits of using LRR replacement tires and for keeping tires properly inflated. Additionally, to increase the result from this option consumers could be provided tire pressure measuring devices and minimum tire efficiency standards could be adopted.

Background

Vehicle tires that are under-inflated result in increased energy consumption. According to a recent survey by the National Highway Transportation Safety Administration (NHTSA), 27 percent of passenger cars and 32 percent of light trucks are driven with one or more substantially under-inflated tires.[1] An under-inflated tire is defined as being at least 8 pounds per square inch (psi) below manufacturer's recommended pressure, which is 25 percent below common recommended inflation pressure of 32 psi. According to the Environmental Protection Agency, under-inflated tires can lower gasoline fuel economy (in miles per gallon) by 0.40 percent for every 1 psi drop in pressure of all four tires.[2]

According to the American Council for an Energy Efficient Economy, LRR tires are introduced as original automotive equipment to help meet Corporate Average Fleet Economy standards in new vehicles.[3] LRR tires can reduce the negative effect of friction by up to 20 percent, providing a fuel economy improvement of 3 to 4 percent without compromising vehicle safety and handling.[4]

Because tires are not currently labeled with energy related information and consumer information on this subject is lacking, consumers are unaware of the fuel consumption implications of their choices for purchasing replacement tires. Consequently, consumers purchase many after-market replacement tires that result in greater energy consumption compared to the results from original equipment tires.

The Natural Resources Defense Council estimates the energy savings from fuel-efficient replacement tires could approach 5.4 billion barrels of oil over the next 50 years, the equivalent of 70 percent of the total oil available from the Arctic Refuge in Alaska.[5]

Status

Senate Bill 1170 (Chapter 912, Statutes of 2001) directs the Energy Commission to evaluate ways to increase automotive fuel-efficiency in the state government's motor vehicle fleet by 10 percent. The Energy Commission and the State Department of General Services will jointly study the potential fuel-economy improvements possible through state government purchase of fuel-efficient vehicles. The Energy Commission will conduct a separate evaluation on the use of more energy-efficient tires.[6] Unfortunately, all of the results of this evaluation did not become available in time to be fully considered in this analysis. The estimated range of efficiency impact in this evaluation, however, is consistent with the efficiency improvement value used in the AB 2076 analysis. The agencies will complete their studies by January 31, 2003, including recommendations on a state tire efficiency program.

Assumptions and Methodology

In the base case demand forecast, about 39 percent of California's light-duty vehicles are pickup trucks (includes minivans and sport utility vehicles) and 61 percent are passenger cars. Applying NHTSA data on tire under-inflation, staff calculated that about 30 percent of the State's light-duty fleet population operate with under-inflated tires.[7] Staff assumes that a consumer education campaign on tire inflation could influence up to 30 percent of these motorists to inflate their tires properly.[8] Based on NHTSA data and the relationship of rolling resistance, tire pressure, and increased fuel economy, NRDC estimates that if all tires were properly inflated, on-road passenger vehicle fuel consumption would decrease by about 2 percent.[9]

In this analysis, based on the life of average tires, and data obtained from Michelin on the rolling resistance of tires, staff assumes that approximately 60 percent of the on-road vehicle fleet have replacement tires, and that 80 percent of those vehicles have tires that are not low-rolling resistance tires.[10] A consumer education campaign on LRR tires is assumed to influence 30 percent of the motorists who normally do not purchase LRR replacement tires. When combined, these values result in an increase in the fraction of light-duty vehicles using LRR tires by about 14.4 percent (0.6 x 0.8 x 0.3 = 0.144).

A spreadsheet is used to model the use of LRR tires and tire inflation practice for each calendar year for a calculated fraction of the light-duty vehicle population in California. Each year an incremental consumer expenditure for LRR tires is calculated. The annual fuel savings that result from using these tires is also determined. A separate, but similar, set of calculations is performed for a fraction of light-duty vehicles that change to operate with properly inflated tires. The energy effects of these choices are combined and projected to 2030.

For each year in the calculation, the same fraction of consumers is assumed to adopt the desired action. Since the life of a LRR tire was assumed to be three years, the magnitude of fuel savings due to this choice builds over three calendars years and then reaches a steady-state condition. For the tire inflation choice, steady-state occurs in the first year of implementation. In this analysis, consumers are not expected to retain a lasting habit of buying LRR tires or using better tire maintenance practices. Thus, the fraction of consumers making these choices does not increase over time.

Low-Rolling Resistance Tires. Assumptions for the analysis on LRR tires include:

- Minimum estimated annual cost for a public outreach campaign is $10 million. This includes information on proper tire inflation.

- Annual cost of establishing tire rating and labeling system and tire testing is $1 million.

- Estimated cost per vehicle for low-rolling tires: $40/vehicle/3-years.[11]

- Annual fuel savings per vehicle = $37.19 per vehicle ($1.64 per gallon). Annual vehicle fuel savings based upon annual mileage of 12,500 miles, vehicle fuel economy of 21.2 miles per gallon gasoline, and a fuel economy improvement of 4 percent per vehicle. The amount of fuel reduction that results from an efficiency improvement is calculated from the following relationship. Let F_c = original fuel consumption for a given distance traveled and original vehicle fuel economy; F_r = reduced fuel consumption due to an efficiency improvement, e (percent/100), thus

$$F_r = [1 - 1/(1 + e)] [F_c]$$

- Gasoline price was from the base case forecast of $1.64 per gallon, plus or minus $0.17 per gallon (one standard deviation in the monthly average retail price over the most recent 5 calendar year period).

- Annual vehicle reduction in fuel use = 22.68 gallons per vehicle.

- Prior to the education campaign, LRR tires were sold with little or no knowledge regarding the fuel economy benefit of the tires. Because of the campaign, the number of units sold would increase and all buyers would recognize that the LRR tires have increased utility. All of the buyers now understand that the tire provides additional benefits for what they were willing to pay. Thus, from a societal perspective, the consumer benefits have increased (greater utility per unit cost). At a minimum, the consumer benefit would be equal to the annual fuel savings minus the total incremental cost for the tires. Since benefits accrue over the life of the tire, these monetary components are expressed as present values.

- The change in government revenues would be the sum of reduced collection of fuel excise taxes and the costs for the education campaign and tire testing program. This is expressed as a present value.

- Net benefits would be the sum of consumer benefits and the change in government revenue. If the government revenue declines, it is a negative value.

Proper Air Inflation for Tires. Assumptions for the analysis on proper air inflation for tires include:

- Minimum estimated annual cost for a public outreach campaign is $10 million. This includes information on energy-efficient tires.

- Cost to consumer for each vehicle: $0.00 (Zero).

- Annual fuel reduction: 11.79 gallons per vehicle (2% fuel savings).

- Annual fuel savings value: $19.34 per vehicle ($1.64 per gallon). Annual vehicle fuel savings based upon annual mileage of 12,500 miles, vehicle fuel economy of 21.2 miles per gallon gasoline, and a reduction in annual fuel consumption of 2 percent per vehicle.

- Improved inflation monitoring has a beneficial effect on tire life but is not included in this cost-benefit analysis.

- The consumer benefit is equal to the value of the fuel savings. As with the LRR tires, these monetary components are expressed as present values.

- The change in government revenue is the sum of reduced fuel excise taxes and the cost of the education campaign, expressed as a present value.

- The net benefit is the sum of consumer benefits and the change in government revenue. If the government revenue declines, it is a negative value.

Results

Cost-Benefit Considerations. When direct out-of-pocket expenses are accounted for, consumers experience a present value benefit (savings) that is estimated to range from about $1.0 to $5.2 billion over the time periods evaluated (Tables 1B-1, 1B-2, and 1B-3). Savings are higher at higher fuel prices and increase over time.

During the same time periods, government revenue is estimated to experience a present value loss due to reduced collection of fuel excise taxes and expenditures for a public media campaign on consumer education and a tire testing program. The change in revenue is not linked to the price of fuel. These losses range from about $0.4 to $1.5 billion. About 90 percent of the loss is caused by reduced excise tax collection from fuel sales. Thus, the economic results are relatively independent of the cost for the media campaign and tire testing program. Losses increase over time.

The combined effect of the consumer benefit and change in government revenue is a present value net benefit that ranges from about $0.6 to $3.7 billion. Net benefits are higher at higher fuel prices and increase over time.

Single year cost-benefit values are shown in the summary tables. These values are representative of annual savings and losses in future years and do not employ present value considerations. They demonstrate similar trends as the economic results expressed in present values.

Conventional Fuel Displaced. Based upon the current fleet average fuel economy, the amount of annual reduced gasoline consumption due to this option is estimated to be about 1.8 percent of the annual base case demand. The amount of fuel use is not linked to the price of fuel.

Cost per Gallon of Fuel Displaced. This option is estimated to save money for consumers for each gallon of gasoline displaced. The annual consumer benefit ranges between $0.97 to $1.31 per gallon. However, the reduced government revenue from fuel excise taxes causes government losses for each gallon of gasoline displaced, about $0.37 per gallon. For the annual net benefit, the cost per gallon displaced is a savings that ranges from $0.60 to $0.94 per gallon. The analyses of other elements that can provide consumer benefits in Task 1 may improve the overall cost-benefit of this option.

Key Drivers and Uncertainties

The key drivers in this analysis are:

- The cost of low-rolling resistance replacement tires.

- The increase in fuel economy from improved tire inflation practices and LRR tires.

- The tire life of a LRR tire.

- The fractions of the fleet population currently using less efficient replacement tires and operating with under-inflated tires.

- Consumer response to information on proper tire inflation and tire efficiency characteristics.

- If the TREAD Act requires manufacturers to provide inflation pressure monitoring devices in new vehicles, additional fuel economy gains can be expected.[12] Inflation monitoring devices will likely increase the proportion of vehicles with properly inflated tires. This would change the fuel demand forecast of the base case and reduce the opportunity for savings calculated in this analysis. The change in consumer practice could eventually approach 100 percent, resulting in a 1 percent reduction in annual gasoline use. However, this additional reduction would not be achieved until the entire California vehicle population was replaced with vehicles built after implementation of the TREAD Act. A complete fleet turnover might then be achieved in the 2020 to 2030 time frame.

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[1] U.S. Department of Transportation National Highway Traffic Safety Administration, Consumer Information regulations Uniform Tire Quality Grading Standards, 60 Fed. Reg. 27472 (May 1995).

[2] United States Environmental Protection Agency Website, www.fueleconomy.gov, 2002.

[3] John DeCicco, American Council for an Energy-Efficient Economy, Facsimile, July 11, 2000.

[4] K.G. Duleep, National Highway Transportation Safety Administration Docket, August 1995.

[5] "A Responsible Energy Policy for the 21[St] Century" National Resources Defense Council, March 2001.

[6] California State Fuel-Efficient Tire Report, Volumes 1 and 2, www.energy.ca.gov/transportation/tire_efficiency/documents/index.html, January 2003.

[7] NHTSA data: 27 percent of passenger cars, 32 percent of light trucks are driven with one or more substantially under-inflated tires; applying to California's fleet, (32 percent x 39 percent light trucks) + (27 percent x 69 percent passenger cars) = 31 percent (rounded to 30 percent) of light-duty vehicles in California with under-inflated tires.

[8] This value is estimated from other public information programs. See the discussion in the Methodology Section (Attachment A).

[9] Roland Hwang, National Resources Defense Council calculations via e-mailed spreadsheet, March 2002.

[10] Michelin, August 9, 1994.

[11] Informal staff survey and cost judgment, David Ashuckian, August 2002.

[12] National Highway Transportation Safety Administration, “TREAD Milestones”, www.nhtsa.dot.gov/cars/rules/ rulings/tread/MileStones/index.html.

Table 1B-1

Summary of Analysis Results

Option 1B: Fuel-Efficient Replacement Tires and Tire Inflation

($1.47 per gallon gasoline)

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$1,000	($430)	$569
2002 to 2020	$2,676	($1,064)	$1,611
2002 to 2030	$3,848	($1,504)	$2,343

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$300	($114)	$186
2020	$341	($129)	$212
2030	$391	($146)	$239

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	1,514	2010	308	1.8%
2002 to 2020	4,831	2020	352	1.8%
2002 to 2030	8,634	2030	405	1.8%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$0.97	($0.370)	$0.60
2020	$0.97	($0.370)	$0.60
2030	$0.97	($0.360)	$0.60

Table 1B-2

Summary of Analysis Results

Option 1B: Fuel-Efficient Replacement Tires and Tire Inflation

($1.64 per gallon gasoline)

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$1,193	($430)	$763
2002 to 2020	$3,161	($1,064)	$2,097
2002 to 2030	$4,540	($1,504)	$3,036

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$353	($114)	$239
2020	$401	($129)	$272
2030	$460	($146)	$313

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	1,514	2010	308	1.8%
2002 to 2020	4,831	2020	352	1.8%
2002 to 2030	8,634	2030	405	1.8%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$1.14	($0.370)	$0.77
2020	$1.14	($0.370)	$0.77
2030	$1.14	($0.360)	$0.77

Table 1B-3

Summary of Analysis Results

Option 1B: Fuel-Efficient Replacement Tires and Tire Inflation

($1.81 per gallon gasoline)

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$1,386	($430)	$956
2002 to 2020	$3,648	($1,064)	$2,584
2002 to 2030	$5,233	($1,504)	$3,729

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$405	($114)	$291
2020	$461	($129)	$332
2030	$528	($146)	$382

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	1,514	2010	308	1.8%
2002 to 2020	4,831	2020	352	1.8%
2002 to 2030	8,634	2030	405	1.8%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$1.31	($0.370)	$0.94
2020	$1.31	($0.370)	$0.94
2030	$1.31	($0.360)	$0.94

Staff Paper on Option 1C
Government Fleets

Description

This option would require all government fleets in California, including local, state, and federal fleets when purchasing new vehicles to select the most fuel-efficient vehicle in each vehicle class for one-third of their purchases. This limit would allow the purchase of special purpose vehicles, such as emergency service pursuit vehicles, that would not necessarily satisfy this criterion.

Background

Based upon descriptions of vehicle size, carrying capacity, or utility, light-duty vehicles are placed in different vehicle classes. This categorization simplifies the marketing and the purchase of vehicles since buyers can immediately screen the number of potential vehicle models to those in the vehicle class of interest. Within each class, a range of fuel economy performance is usually found among the vehicles offered for sale.

There are currently 231,000 light-duty vehicles in government fleets in California; approximately 41,000 of those are in the State of California's own fleet. The historic growth rate of the government vehicle population in California is 2 percent per year.[1]

Status

Government vehicles have historically been purchased to satisfy the needs of each agency and to meet the requirements of the national Energy Policy Act (EPAct) of 1992. Currently, EPAct requires federal and state fleet operators to replace 75 percent of all new vehicles with vehicles that are capable of operating on an alternative fuel. The desired outcome is a reduction in the use of petroleum fuels. There is no requirement, however, that these fleets use an alternative fuel. Since the vast majority of light-duty, alternative fuel vehicles offered for sale have had the capability to also use gasoline, little or no reduction in petroleum use has resulted. In addition, emergency vehicles, local government vehicles, and vehicles that have a gross vehicle weight over 8,500 pounds are exempt from EPAct requirements. However, staff believes that using the most fuel-efficient vehicle available in class would result in greater petroleum fuel reduction than produced by EPAct requirements. Additional data from fleets is required in order to provide a more accurate estimate of the petroleum reductions that would be achieved from this measure.

Assumptions

This analysis assumes that beginning in 2005, one-third of new vehicle purchases each year would meet the criterion of most fuel efficient in vehicle class for that model year. Government fleet vehicles are generally replaced at a rate of 10 percent per year.[2] This turnover rate implies a vehicle service life of 10 years.

An informal survey of two relatively large government fleets, the California Department of General Services Fleet Administration Office (DGS) and Sacramento County, indicates that the annual purchase of law enforcement vehicles can be as high as two-thirds of their total light-duty vehicle acquisitions. This leaves a potential balance of one-third that may have the flexibility to use best-in-class fuel economy as a purchasing criterion.

The average light-duty vehicle fuel economy for the best-in-class vehicle classes purchased by government fleets is assumed to be 28 mpg (combined city and highway, Corporate Average Fuel Economy value). This value is calculated from the best-in-class vehicles purchased by the DGS in 2001 and uses Corporate Average Fuel Economy city and highway fuel economy values measured by the U.S. Environmental Protection Agency.

The average fuel economy for the entire population of light-duty vehicles purchased by DGS in 2001 and considered in this analysis is 21.6 mpg (combined city and highway value). The potential reduction in gasoline use due to the adoption of a best-in-class fuel economy criterion is based on the difference in fuel economy between an average light-duty vehicle and the best-in-class vehicle (21.6 versus 28 mpg).

The best-in-class fuel economy vehicle is generally less expensive than the average vehicle in class. However, since it was assumed that government fleets purchase vehicles through a competitive bid process that emphasizes low cost, the purchase of a best-in-class vehicle would not necessarily reduce or increase vehicle cost to government fleets.

Cases using gasoline prices of $1.47 and $1.81 per gallon were also evaluated. These prices result from a price range of plus or minus $0.17 per gallon from the base case forecast. The standard deviation was based upon a range in historical retail prices.

Consumer benefits will equal the present value of fuel savings over time. The change in government revenue will be equal to the present value reduction in fuel excise taxes. Net benefits will be the sum of consumer benefits and the change in government revenues.

Results

Cost-Benefit Considerations. When direct out-of-pocket expenses are accounted for, government fleets (consumers) experience a present value benefit (savings) that is estimated to range from about $26 to $231 million over the time periods evaluated (Tables 1C-1, 1C-2, and 1C-3). Savings are higher at higher fuel prices and increase over time.

During the same time periods, government revenue is estimated to experience a present value loss due to reduced collection of fuel excise taxes. This loss ranges from about $2 to $43 million. Losses increase over time.

The combined effect of the consumer and government revenue impacts is a present value net benefit that ranges from about $20 to $189 million. Net benefits increase over time. Single year cost-benefit values represent annual savings and losses in future years and do not employ present value considerations.

Conventional Fuel Displaced. Based upon the current fleet average fuel economy, the amount of annual reduced gasoline consumption due to this option is estimated to be about 0.1 percent of the annual base case demand. Since the government fleet population is small compared to the State's entire light-duty vehicle population, the percentage fuel reduction due to more efficient government fleets is also small.

Cost per Gallon of Fuel Displaced. This option is estimated to save money for government fleets (consumers) for each gallon of gasoline displaced. Over the long-term (beyond 2010), the consumer savings range from about $1.81 to $1.47 per gallon. These estimates do not include present value considerations.

The reduced government revenue from fuel excise taxes causes government losses for each gallon of gasoline displaced, about $0.33 per gallon.

For the net benefit, the cost per gallon displaced is a savings of between $1.14 to $1.48 per gallon. The analyses of other elements that can provide consumer benefits in Task 1 may improve the overall cost-benefit of this option.

Key Drivers and Uncertainties

The key uncertainties in this analysis involve:

- The numbers of annual new vehicle purchases by California's local, state, and federal fleets.
- Current and future fuel economy performance of government fleets.
- The fraction of new purchases that could be selected from a set of best-in-class fuel economy vehicles.
- The possible limitation imposed by EPAct requirements to purchase alternative fueled vehicles instead of fuel-efficient gasoline vehicles. This could reduce the purchased number of best-in-class vehicles.
- The numbers of flexible fuel or dual fuel vehicles in government fleets that currently use an alternative fuel are uncertain.
- The incremental cost between a best-in-class vehicle versus the average vehicle.

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[1] California Department of Motor Vehicle Data, 2001.

[2] Discussion with Department of General Services, Office of Fleet Procurement staff, November 2001.

Table 1C-1

Summary of Analysis Results
Option 1C: Government Fleets
($1.47 per gallon gasoline)

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$26	($6)	$20
2002 to 2020	$116	($26)	$90
2002 to 2030	$188	($43)	$145

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$10	($2)	$8
2020	$20	($5)	$16
2030	$25	($6)	$19

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	24	2010	7	0.04%
2002 to 2020	144	2020	14	0.07%
2002 to 2030	297	2030	17	0.07%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$1.47	($0.330)	$1.14
2020	$1.47	($0.330)	$1.14
2030	$1.47	($0.330)	$1.14

Table 1C-2

Summary of Analysis Results
Option 1C: Government Fleets

($1.64 per gallon gasoline)

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$29	($6)	$23
2002 to 2020	$130	($26)	$103
2002 to 2030	$210	($43)	$167

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$12	($2)	$9
2020	$23	($5)	$18
2030	$27	($6)	$22

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	24	2010	7	0.04%
2002 to 2020	144	2020	14	0.07%
2002 to 2030	297	2030	17	0.07%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$1.64	($0.330)	$1.31
2020	$1.64	($0.330)	$1.31
2030	$1.64	($0.330)	$1.31

Table 1C-3

Summary of Analysis Results
Option 1C: Government Fleets

($1.81 per gallon gasoline)

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$32	($6)	$26
2002 to 2020	$143	($26)	$117
2002 to 2030	$231	($43)	$189

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$13	($2)	$10
2020	$25	($5)	$20
2030	$30	($6)	$25

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	24	2010	7	0.04%
2002 to 2020	144	2020	14	0.07%
2002 to 2030	297	2030	17	0.07%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$1.81	($0.330)	$1.48
2020	$1.81	($0.330)	$1.48
2030	$1.81	($0.330)	$1.48

Staff Paper on Option 1D
Vehicle Maintenance Practices

Description

This option involves a State campaign to educate motorists on the benefits of improved maintenance practices to reduce the future demand for gasoline consumption.

Background

In the short-term, improving the efficiency performance of California's vehicle population can be achieved by focusing on vehicle related measures that do not require the time of technology advancement and can be initiated solely through individual or State action. In general, these actions might include periodic engine tune-ups, engine lubrication, changes of air and oil filters, and proper tire inflation levels.

The U.S. Department of Energy estimates that maintenance practices can improve individual vehicle fuel economy by 1 to 10 percent for air filters and 1 to 2 percent for oil and oil filter changes.[1]

Status

It is likely that engines in California vehicles that are not operating well are being identified through the State's Smog Check Program. A large fraction of vehicles that could improve fuel economy performance through a tune-up are already accounted for as part of the base case demand forecast. The potential impact of maintaining proper tire inflation is being evaluated under a separate analysis related to tire replacement and maintenance. As a result, the estimated fuel reduction from improved vehicle maintenance practices will focus on periodic changing of engine lubrication and air and oil filters.

Survey data from the Car Care Council indicates that in 2000, 10 percent of the vehicle population has an air filter requiring replacement and 20 percent of the vehicle population has exceeded their oil and filter change interval.[2] These values were used to calculate the upper bound fraction of the fleet population (opportunity fleet) that might contribute to improved fuel economy.

Assumptions

Individual vehicle fuel economy improvement is 2 percent for air filter changes and 2 percent for oil and oil filter changes. Staffs assumed that the Smog Check Program finds air filter changes and oil and oil filter changes that have efficiency improvements beyond 2 percent.

Assumed cost for air filter change is $15 (biennial) and for oil and oil filter change is $25 (annual).

The air filter would be changed every other year ($15/filter). Oil and filter changes would occur twice a year (about $5.50/filter, $1.35/quart of oil, 5 quarts/oil change).[3] No specific cost assumption was made for labor expenses if automotive service providers performed these practices.

Staff assumed an education campaign would influence 30 percent of the opportunity fleet to perform more periodic oil and oil filter and air filter changes. A more accurate estimate will likely require actual market testing to determine the percentage of consumers influenced by a campaign and its related investment level.

Staff assumed a consumer education campaign to inform motorists on the benefits of improved maintenance practices would have an annual cost of $10 million. A more accurate cost estimate will likely require actual market testing to determine a limiting cost-benefit ratio. See Attachment A for additional discussion on media campaigns.

The opportunity fleet population is a subset of the projected light-duty vehicle fleet from the base case CALCARS model for the years 2002 through 2020. Values beyond 2020 were extrapolated from the projected trends.

Fuel Reduction Calculation:

R = Reduction in Gasoline Demand
D = Original Gasoline Demand (consumption before fuel economy improvement)
x = fuel economy improvement, percent/100

$$R = \left(1 - \frac{1}{1+x}\right)(D)$$

Example: Calculate the reduction in gasoline demand for a 10% fuel economy improvement and an original demand of 100 gallons.

$$R = \left(1 - \frac{1}{1+10/100}\right)(100)$$

= 9.09 gallons reduced demand

Consumer Benefits, Change in Government Revenues, Net Benefits:

A. Annual Consumer Benefits = (Value of annual gasoline reduction) – (Annual Maintenance Expense), $

B. Annual Change in Government Revenues = Annual Cost of Education Campaign + Reduced Fuel Excise Taxes, $ (a negative value if revenue declines or funds expended). Since this option would potentially reduce the amount of gasoline sold annually, it would also reduce the revenue from fuel excise taxes. For the period of this analysis, the base case gasoline is assumed to use 5.7 percent by volume ethanol. The federal fuel excise tax for gasoline with this ethanol content is $0.154 per gallon (reduced from $0.183 per gallon for gasoline without any ethanol). The state fuel excise tax is $0.18 per gallon gasoline, independent of the amount of ethanol content. Thus, for each gallon of reduced consumption, government revenue would decline by $0.334.

C. Net Benefits = A + B = C, $

Present Value of NetBenefits = Present Value of Consumer Benefits + Present Value of Change in Government Revenues =

$$\sum_{n=2002}^{t} \frac{A_n}{(1+d)^{n-2002}} + \sum_{n=2002}^{t} \frac{B_n}{(1+d)^{n-2002}}$$

where A_n = annual consumer benefit, B_n = annual change in government revenue, d = discount rate (0.05); n = year 2002, 2003,…, t; t is the last year in the present value period. The present value base year is 2002.

Results

Air Filter Changes. As shown in Table 1D-1, 1D-2, and 1D-3, when direct out-of-pocket expenses are accounted for (savings in reduced fuel consumption versus maintenance expenditures), consumers are projected to experience a present value benefit (savings) for changing a vehicle's air filter every other year. The benefit ranges from $65 to $322 million over the present value periods and fuel prices evaluated. Benefits increase with time and with increasing fuel prices.

Since the air filter change results in less fuel consumption, collection of fuel excise tax declines. This loss is combined with the expenditure for an annual consumer education campaign. The total change in government revenue ranges from a present value loss of $73 to $221 million. This estimated loss is not linked to fuel price. The loss increases over time.

When the consumer benefit is combined with the change in government revenue, the net benefit for the air filter change ranges from a present value loss of $8 million to a savings of $101 million. The net benefit is negative (a loss) at the lower range of fuel prices, but is positive at the midpoint and higher fuel price points.

Similar trends are shown for consumer benefits, change in government revenue, and net benefits when expressed in units of $ per gallon of fuel displaced. The consumer benefit ranges from about $0.86 to $1.20 per gallon of gasoline displaced. The net benefit ranges from about $0.04 to $0.48 per gallon of gasoline displaced. These benefits are not expressed as present values. The benefits increase with fuel price and over time.

The annual amount of gasoline displaced by the air filter case is about 0.12 percent of the base case demand. This corresponds to about 20 million gallons of gasoline in 2010, 23 million gallons in 2020, and 26 million gallons in 2030. The amount of displacement increases as the population of vehicles increases. The fuel displacement is not linked to the fuel price.

Oil and Oil Filter Changes. The benefit results for the oil and oil filter case are shown in Tables 1D-4, 1D-5, and 1D-6. These results indicate that the potential value of fuel savings from oil related maintenance is exceeded by the cost for this practice. Thus, the consumer and net benefits are negative (a loss) for the assumed efficiency improvement, maintenance cost, and fuel price range. The present value, consumer benefit loss and net benefit loss ranges from about $15 to $146 million and $90 to $275 million, respectively.

As with the air filter case, government revenue declines due to reduced collection of fuel excise tax and expenditures for a public education program.

The benefits per gallon of gasoline displaced are also negative.

Based upon these results, this case would not be recommended solely for the benefit of fuel savings.

The amount of gasoline displaced by the oil filter case is about the same as for the air filter case, about 0.12 percent of the base case demand.

Recent information provided to the Energy Commission indicates that using synthetic lubrication oils can increase vehicle fuel economy by about 5 percent.[4] The oil change interval may also be doubled in time. If use of such oils become part of normal industry practice, the base case demand forecast for gasoline would decrease by about 4.8 percent. It would also make the consumer benefit positive for the oil and oil filter case if the synthetic oil is no more expensive than the current retail price of about $5 per quart.

Air Filter and Oil and Oil Filter Changes Combined. As shown in Tables 1D-7, 1D-8 and 1D-9, when the air filter case is combined with the oil and oil filter case, the consumer benefit is positive. The benefit ranges from a present value of $20 million to $271 million. This range of benefit is lower than the result for the air filter case alone.

The combined change in government revenue, a revenue decline, is greater than the separate case results.

The combined net benefit is negative. Consumer benefit is exceeded by the decline in government revenue.

The combined cases double the amount of gasoline displaced by the separate cases, about 0.23 of base case demand.

Key Drivers and Uncertainties

- The reduction in petroleum fuel demand is linearly dependent on the number of vehicles that can take advantage of frequent changes in air or oil filters and engine lubrication and the number of operators influenced by the media campaign. The resulting reduction would double if the fraction of the opportunity fleet responding to the media campaign increased to 100 percent from 50 percent. Conversely, the value would decrease by half if 25 percent of the opportunity fleet adopted the practice.

- The consumer benefit result, a savings or a loss, depends on the magnitude of the fuel economy improvement, related annual expenditure, and the cost of gasoline.

- There is uncertainty regarding the fraction of consumers who do not perform maintenance with the frequency recommended by vehicle manufacturers. While statistics were used to estimate the fraction of consumers who have not performed maintenance as recommended by the original equipment manufacturer, these statistics do not indicate when or if the consumer eventually decides to perform routine maintenance. This added knowledge would help to better establish the baseline condition from which we could measure the effect of a change in consumer habit. The analysis did not attempt to determine the proportion of consumers (with an ill-maintained vehicle) who may just delay performing maintenance practices by a fraction of the recommended frequency. Thus, the analysis assumed that the tardy consumers would have skipped the full time increment for recommended maintenance and compared the value of this lost maintenance benefit to the maintenance expenditure. The benefit values shown may then over predict the benefits that would actually occur.

- Normally, there are other benefits that motorists seek and receive when they perform these relatively routine maintenance practices. For example, proper engine lubrication and a well functioning air filter help maintains overall vehicle performance and retards engine wear. The vehicle drives better and engine life is extended. For a large majority of motorists, these other benefits are greater in value than the savings from reduced fuel consumption. Thus, the results projected for cost-benefit underestimate the overall magnitude of consumer benefits for the maintenance options evaluated. Fuel savings can be viewed as an added bonus for the expense of these maintenance practices.

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[1] www.fueleconomy.gov/feg/maintain.shtml, November 2001.

[2] www.carcarecouncil.org, National Car Care Month Inspections, 1996-2000, November 2001.

[3] Informal survey of retail prices for filters and oil at auto parts store, Dan Fong, California Energy Commission, November 2001.

[4] Some recent data on lubricating oil indicates that synthetic oils provide greater efficiency benefit than petroleum-based oils. Vehicle fuel economy when using the synthetic oil can be improved by up to 5 percent compared to conventional oil. The oil change interval might also be extended with a synthetic oil and partially offset its higher cost per unit volume. If a synthetic oil was uniformly used in all vehicles and it provided a 5 percent fuel economy benefit in all light-duty cars, gasoline demand would be reduced by about 4.8 percent from the base case level. This magnitude of fuel reduction would annually save an average motorist about $46 in fuel cost. The annual cost of an oil filter and single oil change per year would be about $25. Thus, the average motorist would experience a net savings of $21 per year. Personal communication, September 19, 2002, between Dan Fong and Dr. Axel Friedrich, Head of Division, Transport and the Environment, Federal Environmental Agency, Germany, axel.friedrich@ uba.de; Cars and Climate-A Transatlantic Coalition presentation, Castrol, D.H./OEM Europe, June, 2001, Washington, D.C.

Table 1D-1

Summary of Analysis Results

Option 1D: Vehicle Maintenance Practices

Air Filter Case, $1.47 per gallon gasoline

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	($45)	($76)	($120)
2002 to 2020	($103)	($165)	($269)
2002 to 2030	($146)	($224)	($370)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	($10)	($17)	($27)
2020	($12)	($18)	($30)
2030	($14)	($19)	($33)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	116	2010	20	0.12%
2002 to 2020	332	2020	23	0.12%
2002 to 2030	580	2030	26	0.12%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	($0.51)	($0.830)	($1.34)
2020	($0.53)	($0.770)	($1.30)
2030	($0.55)	($0.710)	($1.26)

Table 1D-2

Summary of Analysis Results
Option 1D: Vehicle Maintenance Practices
Air Filter Case, $1.64 per gallon gasoline

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$79	($73)	$6
2002 to 2020	$195	($162)	$32
2002 to 2030	$276	($221)	$55

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$21	($17)	$4
2020	$24	($18)	$6
2030	$27	($19)	$8

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	106	2010	20	0.12%
2002 to 2020	321	2020	23	0.12%
2002 to 2030	567	2030	26	0.12%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$1.04	($0.830)	$0.38
2020	$1.03	($0.770)	$0.43
2030	$1.03	($0.720)	$0.48

Table 1D-3

Summary of Analysis Results

Option 1D: Vehicle Maintenance Practices

Air Filter Case, $1.81 per gallon gasoline

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$92	($73)	$19
2002 to 2020	$227	($162)	$65
2002 to 2030	$322	($221)	$101

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$24	($17)	$8
2020	$28	($18)	$10
2030	$31	($19)	$13

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	106	2010	20	0.12%
2002 to 2020	321	2020	23	0.12%
2002 to 2030	567	2030	26	0.12%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$1.21	($0.830)	$0.38
2020	$1.20	($0.770)	$0.43
2030	$1.20	($0.720)	$0.48

Table 1D-4

Summary of Analysis Results

Option 1D: Vehicle Maintenance Practices

Oil and Oil Filter Case, $1.47 per gallon gasoline

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	($45)	($76)	($120)
2002 to 2020	($103)	($165)	($269)
2002 to 2030	($146)	($224)	($370)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	($10)	($17)	($27)
2020	($12)	($18)	($30)
2030	($14)	($19)	($33)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	116	2010	20	0.12%
2002 to 2020	332	2020	23	0.12%
2002 to 2030	580	2030	26	0.12%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	($0.51)	($0.830)	($1.34)
2020	($0.53)	($0.770)	($1.30)
2030	($0.55)	($0.710)	($1.26)

Table 1D-5

Summary of Analysis Results

Option 1D: Vehicle Maintenance Practices

Oil and Oil Filter Case, $1.64 per gallon gasoline

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	($30)	($76)	($105)
2002 to 2020	($69)	($165)	($235)
2002 to 2030	($99)	($224)	($323)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	($7)	($17)	($24)
2020	($8)	($18)	($26)
2030	($10)	($19)	($29)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	116	2010	20	0.12%
2002 to 2020	332	2020	23	0.12%
2002 to 2030	580	2030	26	0.12%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	($0.34)	($0.830)	($1.17)
2020	($0.36)	($0.770)	($1.13)
2030	($0.38)	($0.710)	($1.09)

Table 1D-6

Summary of Analysis Results

Option 1D: Vehicle Maintenance Practices

Oil and Oil Filter Case, $1.81 per gallon gasoline

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	($15)	($76)	($90)
2002 to 2020	($35)	($165)	($200)
2002 to 2030	($51)	($224)	($275)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	($3)	($17)	($20)
2020	($5)	($18)	($22)
2030	($5)	($19)	($24)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	116	2010	20	0.12%
2002 to 2020	332	2020	23	0.12%
2002 to 2030	580	2030	26	0.12%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	($0.17)	($0.830)	($1.00)
2020	($0.19)	($0.770)	($0.96)
2030	($0.21)	($0.710)	($0.92)

Table 1D-7

Summary of Analysis Results

Option 1D: Vehicle Maintenance Practices

Combined Air Filter and Oil and Oil Filter Cases, $1.47 per gallon gasoline

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$20	($102)	($82)
2002 to 2020	$59	($229)	($171)
2002 to 2030	$84	($314)	($231)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$7	($23)	($16)
2020	$7	($25)	($18)
2030	$8	($28)	($19)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	221	2010	40	0.23%
2002 to 2020	653	2020	46	0.23%
2002 to 2030	1,147	2030	53	0.23%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$0.18	($0.580)	($0.40)
2020	$0.16	($0.550)	($0.39)
2030	$0.15	($0.520)	($0.37)

Table 1D-8

Summary of Analysis Results

Option 1D: Vehicle Maintenance Practices

Combined Air Filter and Oil and Oil Filter Cases, $1.64 per gallon gasoline

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$49	($102)	($53)
2002 to 2020	$126	($229)	($104)
2002 to 2030	$177	($314)	($137)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$14	($23)	($9)
2020	$15	($25)	($10)
2030	$17	($28)	($11)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	221	2010	40	0.23%
2002 to 2020	653	2020	46	0.23%
2002 to 2030	1,147	2030	53	0.23%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$0.35	($0.580)	$0.23
2020	$0.33	($0.550)	$0.22
2030	$0.32	($0.520)	$0.20

Table 1D-9

Summary of Analysis Results

Option 1D: Vehicle Maintenance Practices

Combined Air Filter and Oil and Oil Filter Cases, $1.81 per gallon gasoline

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$78	($102)	($25)
2002 to 2020	$192	($229)	($37)
2002 to 2030	$271	($314)	($43)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$21	($23)	($3)
2020	$23	($25)	($2)
2030	$26	($28)	($2)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	221	2010	40	0.2%
2002 to 2020	653	2020	46	0.2%
2002 to 2030	1,147	2030	53	0.2%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$0.52	($0.580)	($0.06)
2020	$0.50	($0.550)	($0.05)
2030	$0.49	($0.520)	($0.03)

Staff Paper on Option 1E
More Efficient On-Road Diesel Medium- and Heavy-Duty Trucks

Description

This option evaluates the potential of more efficient on-road diesel trucks in medium- and heavy-duty vehicle classifications to reduce the demand for diesel fuel.[1] Two scenarios of improved fuel economy are used to project upper and lower bound impacts on future diesel fuel demand in California.

Background

Assessments to determine potential vehicle and truck fuel economy improvement have been conducted since the early seventies. Staff relied on several of those studies to determine the potential for reducing petroleum use from heavy-duty vehicles in this option.

The U.S Department of Energy's Energy Information Administration National Energy Modeling System (NEMS) projects fuel economy improvements based on truck efficiency gains of 0.4 percent per year from a 1982 baseline of 5.2 miles per gallon (mpg).[2] If this improvement rate is maintained, then the fuel economy of heavy-duty trucks (Classes 7 and 8) will have improved to 6.76, 7.04, and 7.33 mpg by 2010, 2020, and 2030, respectively. At the same improvement rate, the improvement potential for medium-duty vehicles (Classes 3-6) could result in fuel economy levels of 13, 13.5, and 14.1 mpg by 2010, 2020, and 2030, respectively.

In another technology assessment, DeCicco cites KG Duleep's (1997) estimate for new heavy-duty truck fuel economy improvements of 1.2 percent per year.[3] This rate of improvement would result in fuel economy values for heavy-duty trucks of 7.3, 8.3, and 9.3 mpg by 2010, 2020, and 2030, respectively. The corresponding numbers for medium-duty vehicles are 14.1, 15.9, and 17.9 mpg by 2010,2020, and 2030, respectively.

A report by the American Council for an Energy-Efficient Economy assesses long-term potential for heavy-duty truck fuel economy improvement as 65 percent by 2030 over 1990 levels.[4] This is equivalent to a 1.65 percent annual improvement rate over the 40 year period.

Staff took a simple average of these three previous estimates and the observed annual fuel economy improvement rate of 1.25 percent in the last two decades to establish a lower bound fuel economy improvement rate of 1.125 percent for this analysis. The fuel economy values generated from the 1.125 percent annual fuel economy improvement rate are used in the Scenario 1 analysis. The fuel economy estimates based on this approach are lower than the 21st Century Program goals discussed below.

Status

The DOE 21st Century Truck Program is a government-industry initiative to double the 2000 fuel economy of a prototype Class 8 truck on a ton-mile/gallon basis by 2010.[5] The Truck Program will also triple the fuel economy of a prototype representative Class 2b-6 vehicle, as well as transit buses, on a miles per gallon basis by 2010, while meeting prevailing emission standards.[6]

Anticipated improvements in diesel vehicle technologies are the bases for the projected efficiency gains. Technology development and commercialization prospects were determined feasible from a comprehensive assessment of potential technologies in the 21st Century Truck Program Roadmap. According to the Roadmap, fuel economy improvements are possible from a suite of technologies that include combustion improvements, vehicle weight reduction, use of hybrid and auxiliary power technologies, aerodynamic improvements, and rolling and inertia resistance improvements.

Assumptions and Methodology

Fuel Economy and Vehicles Miles Traveled. The base case year 2000 fuel economies used for the vehicle classes in this analysis were calculated from data on average vehicle miles traveled and related volumes of fuel consumed. This data was taken from several sources.[7] Staff estimated 12.7 miles per gallon for vehicle classes 3-6 and 6.5 miles per gallon for vehicle classes 7-8. (Staff analyses cover classes 3, 4, 5, 6, 7, and 8. This is a subset of the DOE's program that focuses on classes 2b through 8.) From the same sources staff also determined a fleet average vehicle miles traveled of 36,000 miles for class 3-6 vehicles and 87,000 miles for class 7-8 vehicles. Staff used 16 years as the useful life for this analysis. This is the observed useful life reported in the Gas Research Institute Study for medium- and heavy-duty vehicles.[8] Future fuel economies used in the analysis are discussed later.

Costs. The incremental capital cost (price) of Class 7 and 8 heavy-duty vehicles with technologies to meet the assumed fuel economy target is estimated to be $7,500 by 2020. This incremental cost declines to $3,600 by 2030. The decline in cost is expected to occur from scale-up in manufacturing volume and learning curve effects.

Medium-duty vehicle incremental capital cost is projected to be $5,000 by 2010, rise to $7,000 by 2020, but decline to $3,000 by 2030. The anticipated rising trend for medium-duty vehicle incremental cost through 2020 is due to greater deployment of more expensive hybrid technologies that include fuel cell hybrids and advanced batteries. By 2030, staff estimated that the incremental cost drops by more than half due to scale manufacturing, learning curve effects and a more responsive market. Staff generated these estimates from previous studies that estimated the cost associated with fuel economy improvements in heavy-duty vehicles.[9]

In one such study, Sachs et al. identified eight efficiency improvement technology areas, potential improvement and associated costs.[10] An additional improvement area discussed by Sachs is related to changes in driver behavior. This potential improvement, however, is not used in this analysis. The technology areas are listed in Table 1E-1. It is anticipated that these technologies will be implemented by 2010, if the requisite investments are made for efficiency improvements. The 21st Century Truck Program relies on many of these same broad technology improvement areas.

Table 1E-1. Fuel Economy Improvement Potential and Estimated Cost (price incremental)

Fuel Economy Improvement Area	Delta Benefit (%)	DeCicco (Cost 1992$)	DeCicco (Updated 2001$)	Residual Technology Implementation Factor LB	Residual Technology Implementation Factor UB	Adjusted Costs Lower Bound (LB) Fuel Economy (Cost 2001$)	Adjusted Costs Upper Bound (UB) Fuel Economy (Cost 2001$)
Aerodynamics (Tractor)	14	3,000	3,914	0.25	0.50	590	1,170
Aerodynamics (Trailer)	5	2,000	2,610	0.25	0.75	390	1,170
Engine Control Technology	16	4,000	5,220	0.25	0.50	780	1,570
Other Available Engine Technology	15	1,600	2,088	0.50	0.25	620	310
Advanced Engines	10	10,000	13,048	0.25	0.50	1,960	3,900
Drive Train	7	(1,500)	(1,500)*	N/A	N/A	(1,500)	(1,500)
Tires	8	700	913	0.25	0.50	140	274
Weight Reduction	1	3,000	3,914	0.25	0.25	590	590
*Not updated. Assumed reduction in drive train cost constant and extended due to component simplification and modularization.							

For the technology improvement areas shown in Table 1E-1, staff has estimated lower and upper bound incremental costs to achieve efficiency improvements. The original 1992 data on incremental cost has been scaled to reflect the degree that a 2000 base case vehicle currently includes some of technologies identified within the technology areas. For example, turbo-charging, an improvement technology contained in the Engine Control Technology (ECT) area, is assumed to be already implemented in the base case vehicle. The incremental cost estimate for the ECT area is then reduced by the turbo-charging cost.

Staff used a technology implementation schedule to describe the technology implementation rate for the technology areas. This rate is then used to approximate, in quarter percentile fractions (25 percent increments), the remaining potential for fuel economy improvement and related fraction of incremental cost. These considerations result in the residual technology implementation factors shown in Table 1E-1. The factors are then used to derive adjusted incremental costs for implementation of the fuel economy improvement areas. A similar method was also used by DeCicco.[11]

Staff converted the 1992$ to 2001$ using the California Energy Commission's price inflator-deflator series for the period.[12] Staff reduced the resulting numbers by 60 percent to account for scale manufacturing (reduced component costs due to increased production volume).[13]

For this analysis staff assumed four fuel economies for the classes of vehicles examined. For Class 3-6 vehicles staff used a nominal fuel economy of 17.5 mpg in the year 2020 for the lower bound case. Staff used 25.4 mpg by 2020 to represent an upper bound based on the aggressive targets of the 21st Century Truck Program. Staff used a nominal fuel economy of 8.5 mpg by 2020 for Class 8 trucks for our lower bound case. Staff used 13 mpg by 2020 to represent an upper bound based on the aggressive targets of the 21st Century Truck Program.

Staff estimated costs corresponding to the fuel economy gains by projecting the technology sets most likely to be implemented in the target years as done in previous studies and summing the associated costs. Based on the assumptions and adjustments to the cost ranges inferred from the ACEEE and ORNL studies, the incremental cost to achieve the lower (8.5 mpg) and higher bound (13.0 mpg) fuel economy for a Class 8 truck, by 2020, ranges from $3,600 to $7,500.[14] The incremental cost to achieve these mpg figures ranges from $3,500 to $3,600 for lower bound and higher bound fuel economies by 2030. Staff did not report cost estimates for year 2010 fuel economy improvements because that date is too short a time to achieve the technology penetration levels to have meaningful petroleum fuel use reduction impacts. Staff used a similar approach to estimate the incremental cost for medium-duty vehicles. These incremental costs range from $4,700 to $7,000 by 2020 and $3,000 to $6,700 by 2030 for lower bound (17.5 mpg) and higher bound (25.4 mpg) fuel economy levels. Hybridization accounts for the higher incremental cost for the medium-duty vehicle classes for the upper bound fuel economy. These results are summarized in Table 1E-2.

Table 1E-2. Summary of Incremental Cost (Price) Values and Fuel Economy Estimates

Vehicle Scenario		2020		2030	
		Class 3-6	**Class 7-8**	**Class 3-6**	**Class 7-8**
Lower Bound-Nominal Fuel Economy	mpg	17.5	8.5	17.5	8.5
	cost	$4,700	$3,600	$3,000	$3,500
Upper Bound-Aggressive Fuel Economy	mpg	25.4	13.0	25.4	13.0
	cost	$7,000	$7,500	$6,700	$3,600

Penetration Rates & Scenarios. The advanced technology vehicles in this analysis are deployed according to a future vehicle penetration scenario. The scenario employs different annual sales rates that vary over different time periods according to some plausible constraints and logic. The staff assumes a limiting, annual penetration rate for these advanced vehicles of 7 percent of the existing fleet population. This percentage is the historical maximum for new vehicle sales compared to the existing fleet. A minimum annual penetration rate is 1 percent of the vehicle population. This minimum is half of the 2 percent nominal historical vehicle population growth rate reported in the 1996 World Vehicle Forecast and Strategies. The minimum rate corresponds to 14.3 percent of new vehicle sales.

Staff assumed annual penetration rates for the periods, 2008 to 2010, 2011 to 2020, and 2020 to 2030. These time periods are defined by regulatory milestones, technology phase-in, maturation and product availability, and deployment of competing alternative fuel infrastructure. For the immediate period of 2002 to 2007, the number of advanced technology vehicles entering the fleet population is negligible.

Factors that influence the penetrations rates used in the analysis are the expected higher cost to consumers for new vehicles that meet emission standards and consumer hesitation related to unproven new vehicle characteristics on reliability, durability, and overall performance.

Cost to Meet Emission Standards. Based on published industry information and analysis of costs to comply with emission standards by the U.S. EPA, staff finds that advanced diesel vehicles are likely to cost $15,000 to $30,000 more than diesel vehicles manufactured before October 2002.[15] These costs (presented in Table 1E-3) include emission control components and systems, as well as related vehicle engineering costs to accommodate the new emission control components. This is in addition to the incremental vehicle cost of $3,600 to $7,000 to achieve improved fuel economy. These higher incremental costs are assumed to influence consumer purchase decisions and therefore modulate advanced vehicle penetrations.

Consumer Hesitation. Historically, consumers hesitate to embrace a new technology until its reliability, durability and performance expectations are proven. This is even more so for heavy-duty diesel vehicles that are employed in mission-driven applications. This market reality is expected to constrain the penetration of the advanced technology diesel vehicles for up to the first three years after their introduction.

These factors influenced the penetration rates in the three penetration periods. The following penetration scenarios are likely to emerge as a result of these factors individually and combined, during the three penetration periods the 2002 to 2030 planning period is divided into.

- In the 2002-2007 time frame, sales of advanced new diesels are negligible, limited to prototypes, field trials and demonstrations. This penetration period is negligible for purposes of this analysis.

- In the 2008-2010 period, staff assumed the minimum penetration rate of 1 percent of the vehicle population in the target year or 14.3 percent of the new vehicle sales. During this period consumers buy 2 grams of oxides of nitrogen per brake-horsepower-hr natural gas (NG) and diesel products, now in the market for 5 years, to hedge against the higher priced 0.2 grams of oxides of nitrogen engines entering the market. As a consequence, sales of 0.2 grams of oxides of nitrogen natural gas and diesel vehicles are modest due to product performance uncertainties and delayed customer purchases.

- In the 2011-2020 period, staff assumed a penetration rate equal to the average of the maximum and minimum penetration rates or 57.1 percent of new vehicle sales. During this period, vehicle sales are driven by fleets replacing aging 4.0 and 2.5 grams of oxides of nitrogen engines.

- In the 2021-2030 period, staff assumed that penetration rates peak to about 100 percent of the new vehicle sales as more fleets purchase newer vehicles to replace aging vehicles and to take advantage of the potential fuel savings from the more efficient advanced vehicles.

Table 1E-3
Component Cost Estimate of Emission Compliance Technologies

ROW	Emission Standard Compliance Technology Component, Incremental and Total Price Estimates [14] for Options 1E and 2H (Price estimates based on literature reviews, industry surveys and actual costs paid by some end users - See notes)												
A		CLASS 3-6						CLASS 7 & 8					
B	Technology	Diesel		CNG		LNG		Diesel		CNG		LNG	
C													
D	**MODULE I**	**Near-Term: 2.5 g NOx Standard (Current to 10 years into the future)**											
E		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
F	Cooled EGR (EGR Valve, EGR Cooler, Venturi Mixer, Variable Geometry/Nozzle TurboCharger, Software)	$1,750	$3,000	None	None	None	None	$3,500	$6000 [1,2,3]	None	None	None	None
G	Cooling and related engine systems upgrade	$2,900	$5100 (195-325 HP)	None	None	None	None	$5817 [1] $9875	$7638 [1] (435-450 HP) $12400 (525 - 565 HHP)	None	None	None	None
H	Chassis Reengineering	$4,400	$6,300	In fuel sys price	In fuel sys price	In fuel sys price	In fuel sys price	$8800 [1]	$9500 [1]	Built into fuel system cost	Built into fuel system cost	Built into fuel system cost	Built into fuel system cost
I	DPFs (for PM control where required)	$1,500	$2,500	None	None	None	None	$3,000	$5,000	None	None	None	None
J	Oxidation Catalyst	None	None	In fuel sys price	In fuel sys price	In fuel sys price	In fuel sys price	None	None	Included in fuel sys price	Included in fuel sys price	Included in fuel sys price	Included in fuel sys price
K	Total Delta Price (NOx ctrl only) - F,G,H)	$9,050	$14,400	$0	$0	$0	$0	$18,117	$23,138 (435-450 HP) $27,900 (525-565 HHP)	$0	$0	$0	$0
L	Total Delta Price (NOx & PM ctrl) - K,I)	$10,550	$16,900	$0	$0	$0	$0	$21,117	$28,138	$0	$0	$0	$0
M	MY 2000 base engine @ 4.0g NOx standard	$10,000	$19,000	N/a	N/a	N/a	N/a	$19,000	$26,000	N/a	N/a	N/a	N/a
N	Base engine and fuel system (including fuel storage) price to meet 2.5 g NOx standard (Sum of M,K)	$19,600	$33,400	$19,500	$31,500	N/a or similar to CNG	N/a or similar to CNG	$37,117	$49,138 (435-450 HP) $53,900 (525-565 HHP)	$33,000	$46,300	$35,300	$46,300
O	**MODULE II**	**Matured Market: 0.2 g NOx Standard (12 to 28 years into the future)**											
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
P	Three-Way Catalyst	N/a	N/a	$1,500	$2,500	$1,500	$2,500	N/a	N/a	$2,500	$3000 [10,11]	$2,500	$3000 [10,11]
Q	Lean NOx Trap/NOx Adsorber (Note: h/lpv=high or low production volumes)	$1500 (hpv) $10,000 (lpv)	$1555 (hpv) $15,000 (lpv)	Assume similar to diesel for lean burn NG engs; may be less.	Assume similar to diesel for lean burn NG engs; may be less.	Assume similar to diesel for lean burn NG engines; may be less.	Assume similar to diesel for lean burn NG engines; may be less.	$1500 [3,4,5,6] (hpv) $10,000 (lpv)	$1555 [5] $15,000 [6]	Assume similar to diesel for lean burn NG engines; may be less.	Assume similar to diesel for lean burn NG engines; may be less.	Assume similar to diesel for lean burn NG engines; may be less.	Assume similar to diesel for lean burn NG engines; may be less.
R	SCR	Considered. Not included.						$1500 $10,000	$2500 [5] $15,000 [6]	"	"	"	"
S	Oxidation Catalyst	$600	$1,200	$600	$1,200	$600	$1,200	$600	$1200 [5]	$600	$1200 [5]	$600	$1200 [5]
T	DPFs	$1,500	$2000 [15]	None	None	None	None	$3,000	$5000 [8]	None	None	None	None
U	Total 1 Delta Price (NOx Trap Only) (Sum of K,Q)	$10,550 $19050	$17,955 $29,400	$2100 $11200	$2155 [5] $16,200 [6]	$2100 $11200	$2155 [5] $16,200 [6]	$19617 $33138	$38,138	$2100 $11200	$2155 [5,12] $16,200 [6,12]	$2100 $11200	$2155 [5,12] $16,200 [6,12]
V	Total 2 Delta Price (SCR Only) (Sum of K,R)	Considered. Not included.						19617 $33,138	$38,138	$2100 $11200	$2155 [5] $16,200 [6]	$2100 $11200	$2155 [5] $16,200 [6]
W	Total 3 Delta Price (TWC Only) (Sum of P,S)	N/a	N/a	$2,100	$3,700	$2,100	$3,700	N/a	N/a	$3,100	$4200 [10,11]	$3,100	$4200 [10,11]
X	Total Delta Price (NOx and PM Control) (Sum of T, U)	$12,050 hpv $20,550 lpv	$12,105 $31,400	$2,100	$3,700	$2,100	$3,700	$22,617 $38138	$43,138	3100 $2100	$4200 [10,11] $16,200	$3100 $2100	$4200 [10,11] $16,200
Y	Estimated base engine price @ 2.5g NOx standard (includes fuel sys & storage)(N)	$19,600	$33,400	$19,500	$31,500	N/a or similar to CNG	N/a or similar to CNG	$37,117	$49,138 (435-450 HP) $53,900 (525-565 HHP)	$33,000	$46,300	$35,300	$46,300
Z	Estimated base engine and fuel system (including fuel storage) price to meet 2007 0.2 g NOx and PM standard (Sum of N,Q and T)	$22,600 (hpv) $31,100 (lpv)	$36,955 (hpv) $50,400 (lpv)	$21,600 (vehs w/ stoich engs) $35,100 (vehs w/ lean burn engines)	$34,000 (vehs w/ stoich engs) $35,100 (vehs w/ lean burn engines)	N/a or similar to CNG	N/a or similar to CNG	$41,617	$69,138 (435-450 HP) (hpv) $73,900 [13] (525-565 HP) (lpv)	$36,100 (vehs w/ stoich.engs) $35,100 (vehs w/ lean burn engs.)	$49,400 (vehs w/ stoich engs) $62,500 [13] (vehs w/ lean burn engs.)	$38,400 (Stoich engs.) $37400 (vehs w/ lean burn engs.)	$50,500 (Stoich. Engs.) $62,500 [13] (vehs w/ lean burn engs.)

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Notes for Table 1E-3
1. Heavy Duty Trucking, June 2002, p32.
2. Personal Communication with Vice President, Western Region, DDC, on June 21, 2002.
3. U.S. EPA, "Regulatory Impact Analysis: Control of Emissions of Air Pollution from Highway Heavy-duty Engines," document EPA 420-R-00-010, Chapter 4, "Economic Impact of HD Diesel Standards, " pages 76-80, July 2000.
4. API end-user cost estimate. "Evaluation of Future Diesel Engine Technologies including Exhaust Gas Aftertreatment for the US Market" Contribution from AVL LIST GmbH to American Petroleum Institute, April, 2000.
5. API (April 2000), MECA estimate based on six figure production volumes, 2001.
6. API (April 2000), MECA estimate based on 4 figure production volumes, 2001.
7. Clean Heavy-duty Vehicles: Analyzing Trends in Technologies and Fuels, 3-8:3-9.
8. Cost of DPFs purchased through procurement programs of the South Coast Air Quality Management District and Los Angeles County.
9. Class 7 & 8 NG engines max commercial power rating to date is 425 HP. Price of $23,000 used as base to add fuel system and storage system costs.
10. Inferred from the MECA cost estimates for SCR and NOx trap systems in 10,000 production volumes, Note 6, and the historical 5:1 cost relationship between stationary applications of NOx traps and SCR systems and three-way catalyst technologies as reported by James Cole of South West Research Institute.
11. Personal communication with James Cole, Assistant Director for Engine Research, South West Research Institute, June 26, 2002.
12. Lean burn NG engines will require NOx trap or SCR to achieve 0.2g NOx level. Treated as same as the cost for the diesel engine application. However, the reduction required for the NG engine to meet the 0.2g NOx standard is less than that for the diesel engine. As a result, the price for NG engine NOx trap systems may be less than that for diesels.
13. Chassis reengineering costs to adapt SCR, or NOx traps not included.
14. Subject to continuous refinement as more updated information becomes available.
15. Currently prices at $3000 to $5000 as a retrofit option. We assume $1500 to $2000 as OEM price.
16. Class 3-6 emission control estimates extrapolated by assuming 50% reduction in the price from units for class 7 and 8 vehicles. Costs amortized over larger vehicle numbers and less complex integration, and smaller number of engine platforms.

The vehicle penetrations in the three penetration periods account for the composite populations in the milestone years for the analysis.

Scenarios. Two scenarios of improved fuel economy are used to project upper and lower bound impacts on future diesel fuel demand in California. One scenario under this option assumes implementation of a national fuel economy standard for the heavy-duty vehicle fleet based on the U.S. Department of Energy's (DOE) 21st Century Truck Program targets.[16] Another scenario assumes fuel economy targets that are less aggressive than the 21st Century Program targets. The less aggressive fuel economy improvement scenario is based on previous studies that suggest modest efficiency gain potential for medium- and heavy-duty vehicles.[17]

Scenario 1 (Nominal Fuel Economy Improvement). The first scenario is a lower bound scenario. In this scenario staff assumes fuel economy targets that are less aggressive than the 21st Century Program targets. The less aggressive fuel economy improvement scenario is based on previous studies that suggest modest efficiency gain potential for medium- and heavy-duty vehicles. The penetration rates for Scenario 1 are varied according to the schedule in Table 1E-4 as a fraction of new vehicle sales to correspond to product development, commercialization schedules, and implemented policy initiatives. Moderate fuel economy improvements (38 percent for medium duty and 30 percent for heavy duty by 2030 over year 2000 levels) are also derived. Note that these do not meet the DOE's 21st Century Truck Program goals, which rely on breakthrough technologies. The composite fuel economy improvement is based on the average of the observed historical fuel economy improvement rate for heavy-duty vehicles and model projections from studies performed by the ACEEE and the U.S. Department of Energy's Energy Information Administration NEMs.

Table 1E-4. Interactive Penetration Rates and Periods for Advanced Heavy-Duty Diesel as a Fraction of New Vehicle Sales (percent)

Period	Class 3-6	Class 7 & 8
2002-2007	Negligible	Negligible
2008-2010	14.3	14.3
2011-2020	57	57
2021-2030	100	100

Based on the penetration rate assumptions, the number of new vehicles using more efficient diesel technologies, and entering service, in the relevant milestone years are estimated. The corresponding average absolute penetration rates as a fraction of the existing vehicle population are about 1,000 new vehicles per year for 2002 to 2010, 6,300 vehicles per year for 2011 to 2020 and 11,000 vehicles annually from 2021 through 2030.

Scenario 2 (Aggressive Fuel Economy Improvement). The second scenario is an upper bound scenario. Under this scenario, staff assumes implementation of a national fuel economy standard for the heavy-duty vehicle fleet based on the U.S. Department of Energy's (DOE) 21st Century Truck Program targets. The penetration rates for Scenario 2 are according to the schedule in Table 1E-4 as a percent of the new vehicle sales in the relevant years to correspond to product development, commercialization schedules, and implemented policy initiatives. Aggressive fuel economy improvements (100 percent for classes 3-6 and 100 percent for classes 7-8 by 2030 over year 2000 levels) are also derived. These meet the DOE's 21st Century Truck Program goals, which rely on breakthrough technologies.[18]

Under the assumptions made the California heavy-duty diesel vehicle population is projected to increase from no advanced technology vehicles in 2002 to 7,900 vehicles in 2010, 70,900 vehicles in 2020 and 181,200 vehicles by 2030.

The following assumptions and methodology are common to the two scenarios considered:

- The assumed fuel economy targets are achieved.

- The 21st Century Truck Program Goals are established as federal fuel economy standards for 2010 and beyond.

- All new vehicles sold comply with the assumed federal fuel economy standards.

- All new vehicles sold comply with the prevailing emission standards.

- Variable penetration rates in all vehicle classes with higher rates in some time periods.[19]

- Certain costs for achieving the fuel economy targets and the estimated petroleum displacements include the added capital costs for hybrid propulsion systems in certain vehicle classes, new electrical systems, and new materials. The costs are distributed across the vehicle classes.

Results

Results for the nominal fuel improvement economy (lower bound) are shown in Tables 1E-5 through 1E-7 for Class 3-6 heavy-duty diesel and Tables 1E-8 through 1E-10 for Class 7 & 8, heavy-duty vehicles. Results for the 21st Century Truck fuel economy improvement targets (upper bound) are shown in Tables 1E-11 through 1E-13 for Class 3-6 heavy-duty vehicles and Tables 1E-14 through 1E-16 for Class 7-8 heavy-duty vehicles. The fuel economy implications are discussed separately.

Results are reported for three fuel prices of $1.42, $1.65 and $1.82 per gallon. The following discussion highlights the results for the mid-range price for the lower and upper bound fuel economies. The results for the low and high prices are not discussed but are included in the applicable tables as noted above.

The top left of each table shows consumer benefits, changes in government revenue and net benefits. Costs are represented with parentheses and results are expressed in present value 2001 dollars summed over the time periods indicated. Below that are the savings in each year indicated, in millions of 2001 dollars. The middle box shows the amount and percent of gasoline displaced over the same time periods. The bottom left portion of the table shows consumer benefits, changes in government revenue and net benefits in the year indicated divided by the gallons saved in the same year to scale the costs by the amount of fuel saved. Major input assumptions are shown in the right portion of each table.

Class 3-6 Heavy Duty Diesel Lower Bound Fuel Economy. Table 1E-6 displays the summary results for Class 3-6 heavy-duty advanced diesel vehicles at the mid-point fuel price. These vehicles are predicted to cost an average of $4,700 ($3,500 to $5,900) more due to the estimated 40 percent gain over year 2000 fuel economy.

Negative values in the table are costs either to the consumer or to the government and are shown with parentheses. Between 2002 and 2010, the spreadsheet results indicate that owners would save an extra $1 to $2 million operating these vehicles on a net present value basis in year 2001 dollars. Correspondingly, government would lose $1 million in revenue due to the reduced sale of diesel fuel, for overall net savings of $0 to $2 million. These values grow in later years. Summed from 2002 to 2030, consumers would save an extra $151 to $217 million dollars while government would lose $80 million, for net savings of $71 to $137 million, all on a net present value basis in year 2001 dollars.

On the other hand, Class 3-6 heavy-duty vehicles would displace 0.1 percent of the on road diesel forecasted to be used in 2010, 0.5 percent by 2020 and 0.9 percent by 2030. Displacing each gallon of diesel using more efficient technologies are estimated to result in savings of $0.11 to $0.56 in 2010, $0.39 to $0.73 in 2020 and $0.48 to $0.78 in 2030. These dollars are in year expended, and are not on a net present value basis.

Class 7-8 Heavy Duty Diesel Lower Bound Fuel Economy. Table 1E-9 presents the summary results for Class 7-8 heavy-duty advanced diesel vehicles at the mid-point fuel price. These vehicles are predicted to cost an average of $3,600 ($2,700 to $4,500) more due to the estimated 30 percent gain over year 2000 fuel economy.

Negative values in the table are costs either to the consumer or to the government and are shown with parentheses. Between 2002 and 2010, the spreadsheet results indicate that owners would save an extra $22 to $23 million operating these vehicles on a net present value basis in year 2001 dollars. Correspondingly, government would lose $7 million in revenue due to the reduced sale of diesel fuel, for overall net savings of $15 to $17 million. These values grow in later years. Summed from 2002 to 2030, consumers would save an extra $1.5 to $1.55 billion dollars while government would lose $422 million, for net savings of $1.074 billion to $1.13 billion, all on a net present value basis in year 2001 dollars.

On the other hand, Class 7-8 heavy-duty vehicles achieving the lower bound fuel economy of 8.5 mpg would displace 0.3 percent of the on road diesel forecasted to be used in 2010, 2.8 percent by 2020 and 4.9 percent by 2030. Displacing each gallon of diesel using more efficient technologies in this class are estimated to result in savings of $1.03 to $1.11 in 2010, $1.08 to $1.14 in 2020 and $1.09 to $1.15 in 2030. These dollars are in year expended, and are not on a net present value basis.

Class 3-6 Heavy Duty Diesel Upper Bound Fuel Economy. Table 1E-12 presents the summary results for Class 3-6 heavy-duty advanced diesel vehicles at the mid-point fuel price.

These vehicles are predicted to cost an average of $6,000 ($3,750 to $8,250) more due to the estimated 100 percent gain over year 2000 fuel economy.

Negative values in the table are costs either to the consumer or to the government and are shown with parentheses. Between 2002 and 2010, the spreadsheet results indicate that owners would save an extra $3 to $6 million operating these vehicles on a net present value basis in year 2001 dollars. Correspondingly, government would lose $2 million in revenue due to the reduced sale of diesel fuel, for overall net savings of $1 to $4 million. These values grow in later years. Summed from 2002 to 2030, consumers would save an extra $330 to $454 million dollars while government would lose $143 million, for net savings of $188 to $311 million, all on a net present value basis in year 2001 dollars.

On the other hand, Class 3-6 heavy-duty vehicles would displace 0.1 percent of the on road diesel forecasted to be used in 2010, 1.0 percent by 2020 and 1.7 percent by 2030. Displacing each gallon of diesel using more efficient technologies are estimated to result in savings of $0.35 to $0.83 in 2010, $0.57 to $0.93 in 2020 and $0.64 to $0.96 in 2030. These dollars are in year expended, and are not on a net present value basis.

Class 7-8 Heavy Duty Diesel Lower Upper Bound Fuel Economy. Table 1E-15 presents the summary results for Class 7-8 heavy-duty advanced diesel vehicles at the mid-point fuel price. These vehicles are predicted to cost an average of $7,500 ($5,625 to $9,375) more due to the estimated 100 percent gain over year 2000 fuel economy.

Negative values in the table are costs either to the consumer or to the government and are shown with parentheses. Between 2002 and 2010, the spreadsheet results indicate that owners would save an extra $46 to $49 million operating these vehicles on a net present value basis in year 2001 dollars. Correspondingly, government would lose $14 million in revenue due to the reduced sale of diesel fuel, for overall net savings of $33 to $36 million. These values grow in later years. Summed from 2002 to 2030, consumers would save an extra $3.19 to $3.31 billion dollars while government would lose $897 million, for net savings of $2.29 billion to $2.41 billion, all on a net present value basis in year 2001 dollars.

On the other hand, Class 7-8 heavy-duty vehicles achieving the upper bound fuel economy of 13 mpg would displace 0.6 percent of the on road diesel forecasted to be used in 2010, 6.0 percent by 2020 and 10.5 percent by 2030. Displacing each gallon of diesel using more efficient technologies in this class are estimated to result in savings of $1.03 to $1.11 in 2010, $1.08 to $1.14 in 2020 and $1.10 to $1.15 in 2030. These dollars are in year expended, and are not on a net present value basis.

Key Drivers and Uncertainties

- Assuming that a fuel economy standard will be established to spur industry to achieve the assumed fuel economies.

- Vehicle class distribution does not change.

- Material and manufacturing costs associated with achieving higher fuel economy.

- Vehicle Miles Traveled (affects demand reduction and incremental operating costs).

- Rapid fleet turnover in the years 2015-2030 as vehicle fleet ages and replacement justified by lower operating cost from more fuel-efficient vehicles.

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[1] For this analysis, on-road medium- and heavy-duty vehicles are defined as vehicles weighing greater than 14,000 pounds gross vehicle weight.

[2] DeCicco, John M. "Transportation Energy Issues through 2030," American Council for an Energy-Efficient Economy, December 1997.

[3] DeCicco, John M.; Ledbetter, Marc; Mengelber, Ulrike; Sachs, Harvey M., "Heavy Truck Fuel Economy: A Review of Technologies and the Potential for Improvement," American Council for an Energy-Efficient Economy, January 1992.

[4] Ibid.

[5] Technology Roadmap for the 21st Century Truck Program, U.S. Department of Energy, December 2000.

[6] Applying the 21st Century Program targets to the year 2000 fuel economies on a mile per gallon basis will produce 13 miles per gallon for class 7-8 trucks and 38.1 miles per gallon for class 3-6 trucks. However, due to the uncertainty in implementing the breakthrough technologies to triple the fuel economy for class 3-6 vehicles, the analytical team lowered the fuel economy improvement target for class 3-6 vehicles, to match the 2x multiplier for class 7-8 vehicles. Therefore, this analysis uses a fuel economy target of 25.4 mpg for class 3-6 vehicles.

[7] These sources include "Lower Your Cost of Ownership," Arrow Truck Sales, Inc., March 2002; "1997 Truck Inventory Use Survey," U.S. Census Bureau, U.S. Department of Commerce; "Profile and Segmentation of Medium and Heavy Vehicle Purchase Patterns and Current and Projected Populations," MacKay & Company, February 1995; and California Motor Vehicle Stock, Travel and Fuel Forecast, California Department of Transportation, November 2001.

[8] "Profile and Segmentation of Medium and Heavy Vehicle Purchase Patterns and Current and Projected Populations," MacKay & Company, February 1995.

[9] These studies are DeCicco (cited in endnote 2), DeCicco (cited in endnote 9), Feng (cited in endnote 13), and DeCicco (cited in endnote 14).

[10] DeCicco, John M.; Ledbetter, Marc; Mengelber, Ulrike; Sachs, Harvey M., "Heavy Truck Fuel Economy: A Review of Technologies and the Potential for Improvement," American Council for an Energy-Efficient Economy, January 1992.

[11] Ibid.

[12] E-mail from Lynn Marshall, California Energy Commission, September 2002.

[13] An, Feng; Stodolsky, Frank; Vyas, Anant; Cuenca, Roy; and Eberhardt, James J., "Scenario Analysis of Hybrid Class 3-7 Heavy Vehicles," SAE Paper 2000-01-0989.

[14] DeCicco, John M.; Greene, David L., "Engineering-Economic Analysis of Automotive Fuel Potential in the United States," Oak Ridge National Laboratory, February 2000. Also see DeCicco (cited in endnote 2), DeCicco (cited in endnote 9) and Feng (cited in endnote 13).

[15] "Regulatory Impact Analysis: Control of Emissions of Air Pollution from Highway Heavy-Duty Engines," U.S. Environmental Protection Agency, document EPA 420-R-00-10, July 2000. Also, Heavy Duty Trucking, June 2002, p. 32.

[16] Technology Roadmap for the 21st Century Truck Program, U.S. Department of Energy, December 2000.

[17] See endnotes 2 and 3.

[18] Technology Roadmap for the 21st Century Truck Program, U.S. Department of Energy, December 2000.

[19] As used in this analysis, vehicle penetration rate means a percentage of new vehicles entering the existing fleet population. For this scenario, 100 percent of new vehicles sold meet the fuel economy standards. It is estimated that new vehicle sales are fewer than 10 percent of the existing population in any given year. The penetration rate is varied during the analysis period. It is lower (1 to 2 percent) in some years due to smaller production runs and slower adoption of the technology in certain vehicle classes, and market maturation or saturation. It is higher (5-7 percent) in some years, due to the rapid turnover of the vehicle population assumed to occur in the years 2015-2030 from aging and the availability of more efficient vehicles. The penetration rate is moderate (3-4 percent) in other years as the market matures and demand stabilizes. A composite vehicle class distribution is used in estimating the vehicle penetrations.

Table 1E-5

Summary of Analysis Results

Option 1E: More Efficient On-Road Diesel Medium- and Heavy-Duty Trucks

Low Case, Class 3-6 Diesel Vehicles; Fuel Price: $1.48

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$0	$2	($1)	($1)	($1)	$1
2002 to 2020	$36	$64	($30)	($30)	$5	$34
2002 to 2030	$119	$185	($80)	($80)	$39	$105

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$1	$2	($1)	($1)	($0)	$1
2020	$14	$22	($10)	($10)	$5	$13
2030	$33	$47	($19)	($19)	$14	$28

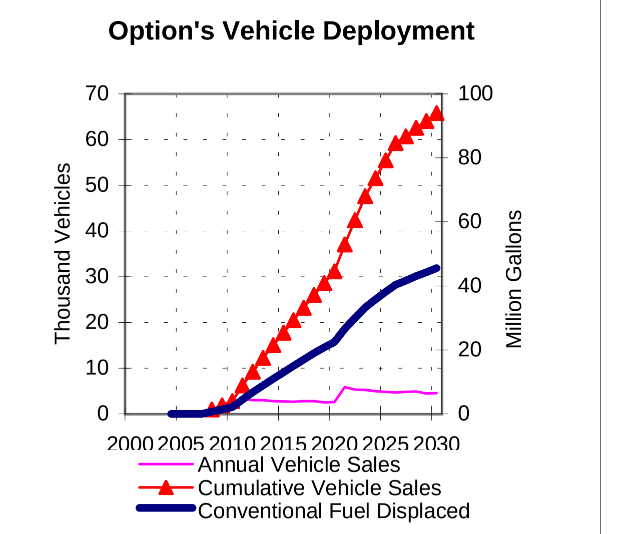
MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	12.5
High Fuel Price Estimate ($/gallon)	$1.480
Low Fuel Price Estimate ($/gallon)	$1.480
For This Option:	
Vehicle Fuel Economy (mi/gallon)	17.5
High Incremental Cost ($ per vehicle)	$5,900
Low Incremental Cost ($ per vehicle)	$3,500
High Fuel Price ($/Gallon)	$1.480
Low Fuel Price ($/Gallon)	$1.480
Vehicle Life (years)	16
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	4	4	2010	2	2	0.1%	0.1%
2002 to 2020	143	143	2020	23	23	0.5%	0.5%
2002 to 2030	521	521	2030	46	46	0.9%	0.9%

(Columns Year through High % are under "Fuel Displaced in Year Indicated".)



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.36	$0.82	($0.42)	($0.42)	($0.06)	$0.39
2020	$0.64	$0.98	($0.42)	($0.42)	$0.22	$0.56
2030	$0.73	$1.03	($0.42)	($0.42)	$0.31	$0.61

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 1E-6

Summary of Analysis Results
Option 1E: More Efficient On-Road Diesel Medium- and Heavy-Duty Trucks

Low Case, Class 3-6 Diesel Vehicles; Fuel Price: $1.65

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$1	$3	($1)	($1)	($0)	$1
2002 to 2020	$48	$76	($30)	($30)	$18	$46
2002 to 2030	$151	$217	($80)	($80)	$71	$137

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$1	$2	($1)	($1)	$0	$1
2020	$18	$26	($10)	($10)	$9	$16
2030	$41	$55	($19)	($19)	$22	$36

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	4	4	2010	2	2	0.1%	0.1%
2002 to 2020	143	143	2020	23	23	0.5%	0.5%
2002 to 2030	521	521	2030	46	46	0.9%	0.9%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.53	$0.99	($0.42)	($0.42)	$0.11	$0.56
2020	$0.81	$1.15	($0.42)	($0.42)	$0.39	$0.73
2030	$0.90	$1.20	($0.42)	($0.42)	$0.48	$0.78

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	12.5
High Fuel Price Estimate ($/gallon)	$1.650
Low Fuel Price Estimate ($/gallon)	$1.650
For This Option:	
Vehicle Fuel Economy (mi/gallon)	17.5
High Incremental Cost ($ per vehicle)	$5,900
Low Incremental Cost ($ per vehicle)	$3,500
High Fuel Price ($/Gallon)	$1.650
Low Fuel Price ($/Gallon)	$1.650
Vehicle Life (years)	16
Discount Rate (%)	5%

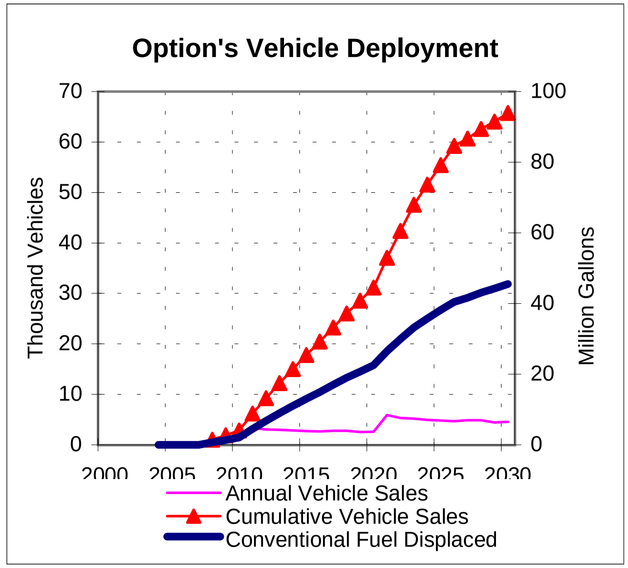


Table 1E-7

Summary of Analysis Results

Option 1E: More Efficient On-Road Diesel Medium- and Heavy-Duty Trucks

Low Case, Class 3-6 Diesel Vehicles; Fuel Price: $1.82

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$1	$3	($1)	($1)	$0	$2
2002 to 2020	$60	$88	($30)	($30)	$30	$58
2002 to 2030	$184	$249	($80)	($80)	$103	$169

Single Year Savings in Millions of 2001 Dollars

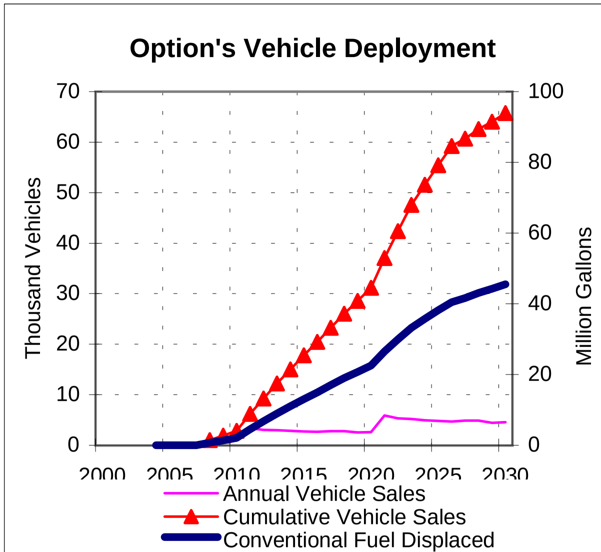
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$1	$2	($1)	($1)	$1	$2
2020	$22	$30	($10)	($10)	$13	$20
2030	$49	$63	($19)	($19)	$29	$43

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	12.5
High Fuel Price Estimate ($/gallon)	$1.820
Low Fuel Price Estimate ($/gallon)	$1.820
For This Option:	
Vehicle Fuel Economy (mi/gallon)	17.5
High Incremental Cost ($ per vehicle)	$5,900
Low Incremental Cost ($ per vehicle)	$3,500
High Fuel Price ($/Gallon)	$1.820
Low Fuel Price ($/Gallon)	$1.820
Vehicle Life (years)	16
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	4	4	2010	2	2	0.1%	0.1%
2002 to 2020	143	143	2020	23	23	0.5%	0.5%
2002 to 2030	521	521	2030	46	46	0.9%	0.9%



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.70	$1.16	($0.42)	($0.42)	$0.28	$0.73
2020	$0.98	$1.32	($0.42)	($0.42)	$0.56	$0.90
2030	$1.07	$1.37	($0.42)	($0.42)	$0.65	$0.95

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 1E-8

Summary of Analysis Results

Option 1E: More Efficient On-Road Diesel Medium- and Heavy-Duty Trucks

Low Case, Class 7-8 Diesel Vehicles; Fuel Price: $1.48

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$19	$21	($7)	($7)	$13	$14
2002 to 2020	$488	$514	($158)	($158)	$330	$356
2002 to 2030	$1,326	$1,387	($422)	($422)	$904	$964

Single Year Savings in Millions of 2001 Dollars

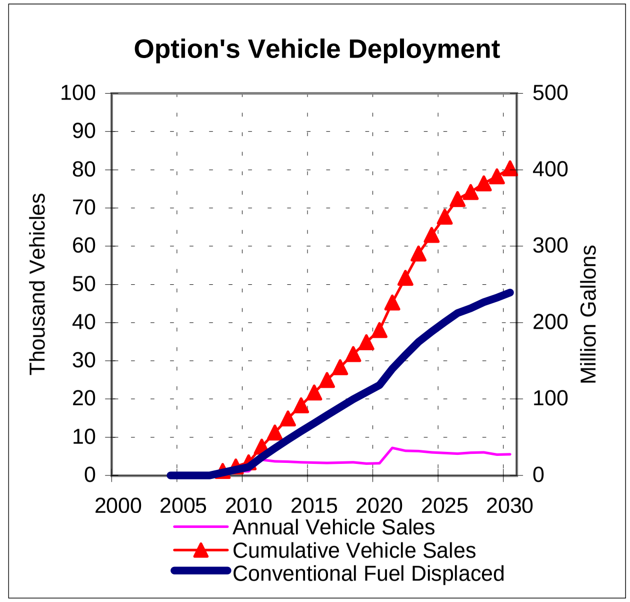
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$14	$15	($5)	($5)	$9	$10
2020	$157	$165	($50)	($50)	$107	$114
2030	$322	$335	($101)	($101)	$221	$234

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.48
Low Fuel Price Estimate ($/gallon)	$1.48
For This Option:	
Vehicle Fuel Economy (mi/gallon)	8.5
High Incremental Cost ($ per vehicle)	$4,500
Low Incremental Cost ($ per vehicle)	$2,700
High Fuel Price ($/Gallon)	$1.48
Low Fuel Price ($/Gallon)	$1.48
Vehicle Life (years)	16
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	22	22	2010	11	11	0.3%	0.3%
2002 to 2020	749	749	2020	118	118	2.8%	2.8%
2002 to 2030	2,740	2,740	2030	239	239	4.9%	4.9%



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$1.28	$1.36	($0.42)	($0.42)	$0.86	$0.94
2020	$1.33	$1.39	($0.42)	($0.42)	$0.91	$0.97
2030	$1.35	$1.40	($0.42)	($0.42)	$0.92	$0.98

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 1E-9

Summary of Analysis Results
Option 1E: More Efficient On-Road Diesel Medium- and Heavy-Duty Trucks

Low Case, Class 7-8 Diesel Vehicles; Fuel Price: $1.65

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$22	$23	($7)	($7)	$15	$17
2002 to 2020	$551	$577	($158)	($158)	$393	$419
2002 to 2030	$1,496	$1,556	($422)	($422)	$1,074	$1,134

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$16	$17	($5)	($5)	$11	$12
2020	$178	$185	($50)	($50)	$128	$135
2030	$363	$376	($101)	($101)	$262	$275

Conventional Fuel Displaced (Million Gallons)

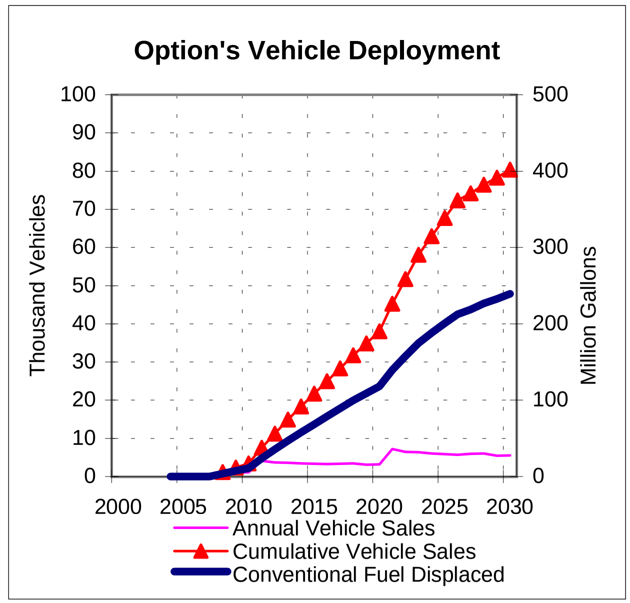
Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
			Fuel Displaced in Year Indicated				
2002 to 2010	22	22	2010	11	11	0.3%	0.3%
2002 to 2020	749	749	2020	118	118	2.8%	2.8%
2002 to 2030	2,740	2,740	2030	239	239	4.9%	4.9%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$1.45	$1.53	($0.42)	($0.42)	$1.03	$1.11
2020	$1.50	$1.56	($0.42)	($0.42)	$1.08	$1.14
2030	$1.52	$1.57	($0.42)	($0.42)	$1.09	$1.15

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.65
Low Fuel Price Estimate ($/gallon)	$1.65
For This Option:	
Vehicle Fuel Economy (mi/gallon)	8.5
High Incremental Cost ($ per vehicle)	$4,500
Low Incremental Cost ($ per vehicle)	$2,700
High Fuel Price ($/Gallon)	$1.65
Low Fuel Price ($/Gallon)	$1.65
Vehicle Life (years)	16
Discount Rate (%)	5%



[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 1E-10

Summary of Analysis Results

Option 1E: More Efficient On-Road Diesel Medium- and Heavy-Duty Trucks

Low Case, Class 7-8 Diesel Vehicles; Fuel Price: $1.82

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$24	$26	($7)	($7)	$18	$19
2002 to 2020	$615	$641	($158)	($158)	$457	$483
2002 to 2030	$1,666	$1,726	($422)	($422)	$1,244	$1,304

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$18	$19	($5)	($5)	$13	$14
2020	$198	$205	($50)	($50)	$148	$155
2030	$404	$417	($101)	($101)	$303	$315

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	22	22	2010	11	11	0.3%	0.3%
2002 to 2020	749	749	2020	118	118	2.8%	2.8%
2002 to 2030	2,740	2,740	2030	239	239	4.9%	4.9%

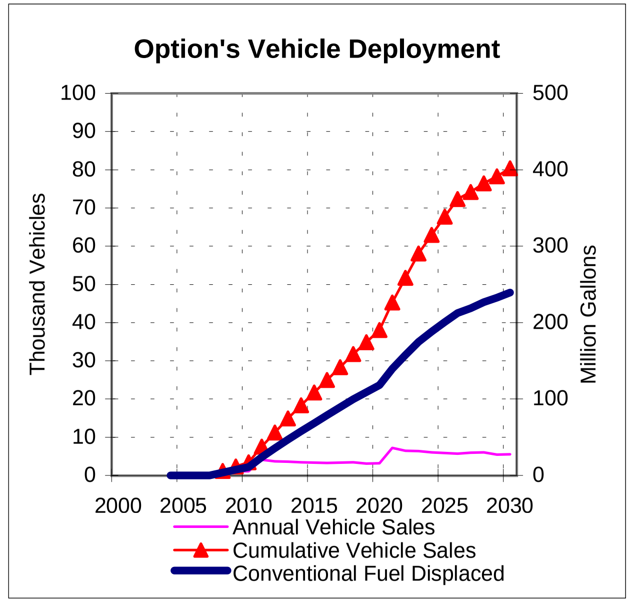
(Fuel Displaced in Year Indicated: Year, Low, High, Low %, High %)

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$1.62	$1.70	($0.42)	($0.42)	$1.20	$1.28
2020	$1.67	$1.73	($0.42)	($0.42)	$1.25	$1.31
2030	$1.69	$1.74	($0.42)	($0.42)	$1.26	$1.32

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.82
Low Fuel Price Estimate ($/gallon)	$1.82
For This Option:	
Vehicle Fuel Economy (mi/gallon)	8.5
High Incremental Cost ($ per vehicle)	$4,500
Low Incremental Cost ($ per vehicle)	$2,700
High Fuel Price ($/Gallon)	$1.82
Low Fuel Price ($/Gallon)	$1.82
Vehicle Life (years)	16
Discount Rate (%)	5%



[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 1E-11

Summary of Analysis Results

Option 1E: More Efficient On-Road Diesel Medium- and Heavy-Duty Trucks

High Case, Class 3-6 Diesel Vehicles; Fuel Price: $1.48

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$2	$5	($2)	($2)	$0	$3
2002 to 2020	$90	$143	($53)	($53)	$36	$89
2002 to 2030	$273	$397	($143)	($143)	$130	$254

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$2	$4	($2)	($2)	$1	$2
2020	$33	$47	($17)	($17)	$16	$30
2030	$72	$98	($34)	($34)	$38	$64

Conventional Fuel Displaced (Million Gallons)

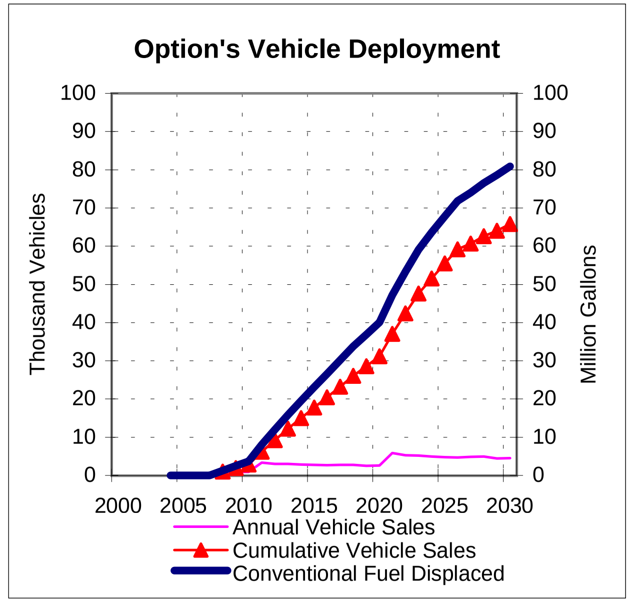
Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	7	7	2010	4	4	0.1%	0.1%
2002 to 2020	254	254	2020	40	40	1.0%	1.0%
2002 to 2030	926	926	2030	81	81	1.7%	1.7%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.60	$1.08	($0.42)	($0.42)	$0.18	$0.66
2020	$0.82	$1.18	($0.42)	($0.42)	$0.40	$0.76
2030	$0.89	$1.21	($0.42)	($0.42)	$0.47	$0.79

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	12.5
High Fuel Price Estimate ($/gallon)	$1.48
Low Fuel Price Estimate ($/gallon)	$1.48
For This Option:	
Vehicle Fuel Economy (mi/gallon)	25.4
High Incremental Cost ($ per vehicle)	$8,250
Low Incremental Cost ($ per vehicle)	$3,750
High Fuel Price ($/Gallon)	$1.48
Low Fuel Price ($/Gallon)	$1.48
Vehicle Life (years)	16
Discount Rate (%)	5%



[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 1E-12

Summary of Analysis Results

Option 1E: More Efficient On-Road Diesel Medium- and Heavy-Duty Trucks

High Case, Class 3-6 Diesel Vehicles; Fuel Price: $1.65

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$3	$6	($2)	($2)	$1	$4
2002 to 2020	$111	$164	($53)	($53)	$58	$111
2002 to 2030	$330	$454	($143)	($143)	$188	$311

Single Year Savings in Millions of 2001 Dollars

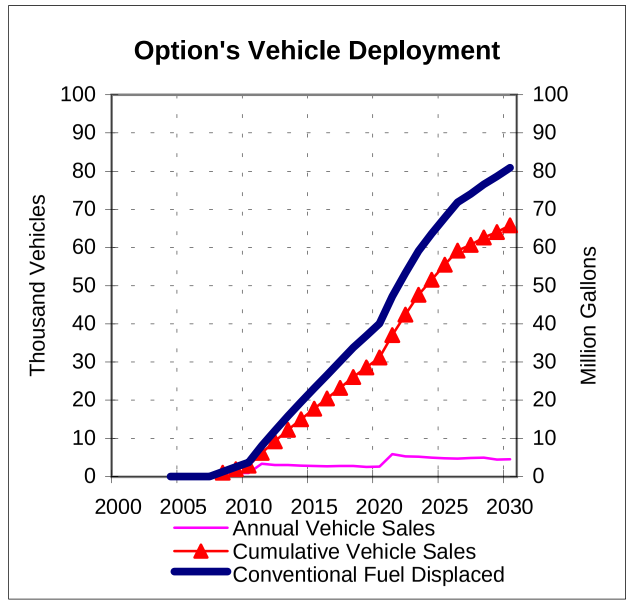
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$3	$5	($2)	($2)	$1	$3
2020	$40	$54	($17)	($17)	$23	$37
2030	$86	$112	($34)	($34)	$51	$78

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	12.5
High Fuel Price Estimate ($/gallon)	$1.65
Low Fuel Price Estimate ($/gallon)	$1.65
For This Option:	
Vehicle Fuel Economy (mi/gallon)	25.4
High Incremental Cost ($ per vehicle)	$8,250
Low Incremental Cost ($ per vehicle)	$3,750
High Fuel Price ($/Gallon)	$1.65
Low Fuel Price ($/Gallon)	$1.65
Vehicle Life (years)	16
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	7	7	2010	4	4	0.1%	0.1%
2002 to 2020	254	254	2020	40	40	1.0%	1.0%
2002 to 2030	926	926	2030	81	81	1.7%	1.7%



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.77	$1.25	($0.42)	($0.42)	$0.35	$0.83
2020	$0.99	$1.35	($0.42)	($0.42)	$0.57	$0.93
2030	$1.06	$1.38	($0.42)	($0.42)	$0.64	$0.96

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 1E-13

Summary of Analysis Results

Option 1E: More Efficient On-Road Diesel Medium- and Heavy-Duty Trucks

High Case, Class 3-6 Diesel Vehicles; Fuel Price: $1.82

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$4	$7	($2)	($2)	$2	$5
2002 to 2020	$133	$186	($53)	($53)	$79	$132
2002 to 2030	$388	$511	($143)	($143)	$245	$369

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$3	$5	($2)	($2)	$2	$4
2020	$46	$61	($17)	($17)	$29	$44
2030	$99	$125	($34)	($34)	$65	$91

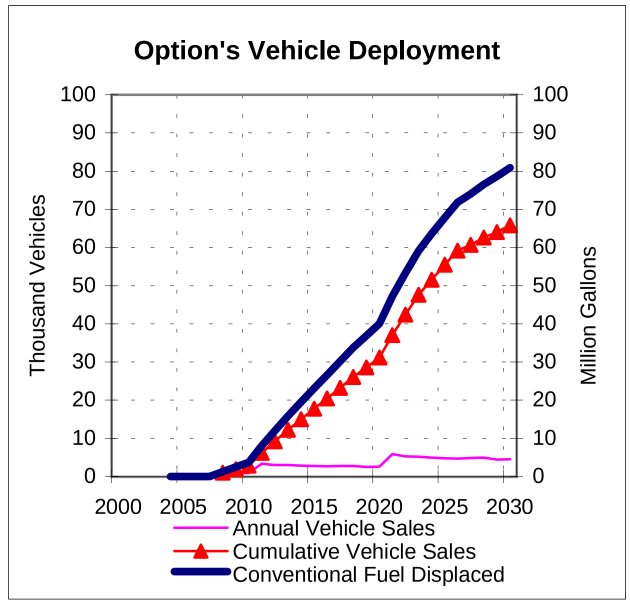
MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	12.5
High Fuel Price Estimate ($/gallon)	$1.82
Low Fuel Price Estimate ($/gallon)	$1.82
For This Option:	
Vehicle Fuel Economy (mi/gallon)	25.4
High Incremental Cost ($ per vehicle)	$8,250
Low Incremental Cost ($ per vehicle)	$3,750
High Fuel Price ($/Gallon)	$1.82
Low Fuel Price ($/Gallon)	$1.82
Vehicle Life (years)	16
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	7	7	2010	4	4	0.1%	0.1%
2002 to 2020	254	254	2020	40	40	1.0%	1.0%
2002 to 2030	926	926	2030	81	81	1.7%	1.7%

(Columns Year through High % are under "Fuel Displaced in Year Indicated".)



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.94	$1.42	($0.42)	($0.42)	$0.52	$1.00
2020	$1.16	$1.52	($0.42)	($0.42)	$0.74	$1.10
2030	$1.23	$1.55	($0.42)	($0.42)	$0.81	$1.13

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 1E-14

Summary of Analysis Results

Option 1E: More Efficient On-Road Medium- and Heavy-Duty Trucks

High Case, Class 7-8 Diesel Vehicles; Fuel Price: $1.48

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$41	$44	($14)	($14)	$27	$30
2002 to 2020	$1,040	$1,094	($336)	($336)	$704	$758
2002 to 2030	$2,825	$2,950	($897)	($897)	$1,928	$2,053

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$30	$32	($10)	($10)	$20	$22
2020	$335	$350	($106)	($106)	$229	$244
2030	$687	$713	($215)	($215)	$471	$498

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	468	468	2010	23	23	0.6%	0.6%
2002 to 2020	1,592	1,592	2020	251	251	6.0%	6.0%
2002 to 2030	5,823	5,823	2030	509	509	10.5%	10.5%

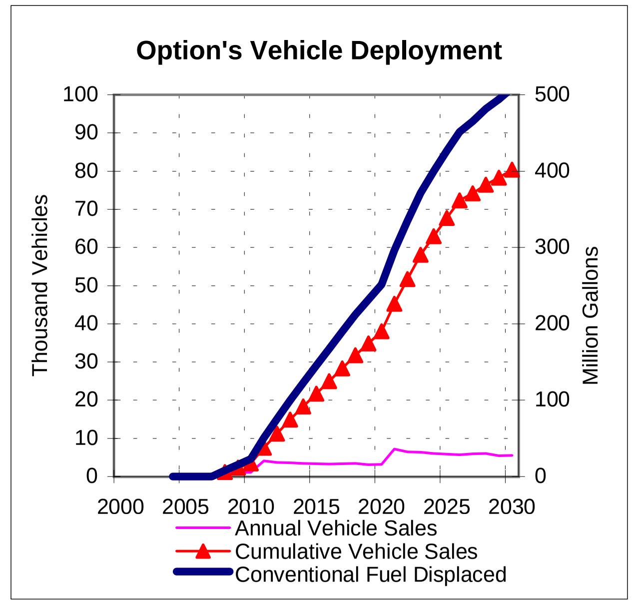
(Columns Year through High % are "Fuel Displaced in Year Indicated".)

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$1.29	$1.36	($0.42)	($0.42)	$0.86	$0.94
2020	$1.33	$1.39	($0.42)	($0.42)	$0.91	$0.97
2030	$1.35	$1.40	($0.42)	($0.42)	$0.93	$0.98

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.48
Low Fuel Price Estimate ($/gallon)	$1.48
For This Option:	
Vehicle Fuel Economy (mi/gallon)	13.0
High Incremental Cost ($ per vehicle)	$9,375
Low Incremental Cost ($ per vehicle)	$5,625
High Fuel Price ($/Gallon)	$1.48
Low Fuel Price ($/Gallon)	$1.48
Vehicle Life (years)	16
Discount Rate (%)	5%



[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 1E-15

Summary of Analysis Results

Option 1E: More Efficient On-Road Medium- and Heavy-Duty Trucks

High Case, Class 7-8 Diesel Vehicles; Fuel Price: $1.65

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$46	$49	($14)	($14)	$33	$36
2002 to 2020	$1,174	$1,229	($336)	($336)	$839	$893
2002 to 2030	$3,185	$3,311	($897)	($897)	$2,288	$2,414

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$34	$35	($10)	($10)	$24	$26
2020	$378	$393	($106)	($106)	$272	$286
2030	$773	$800	($215)	($215)	$558	$584

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	468	468	2010	23	23	0.6%	0.6%
2002 to 2020	1,592	1,592	2020	251	251	6.0%	6.0%
2002 to 2030	5,823	5,823	2030	509	509	10.5%	10.5%

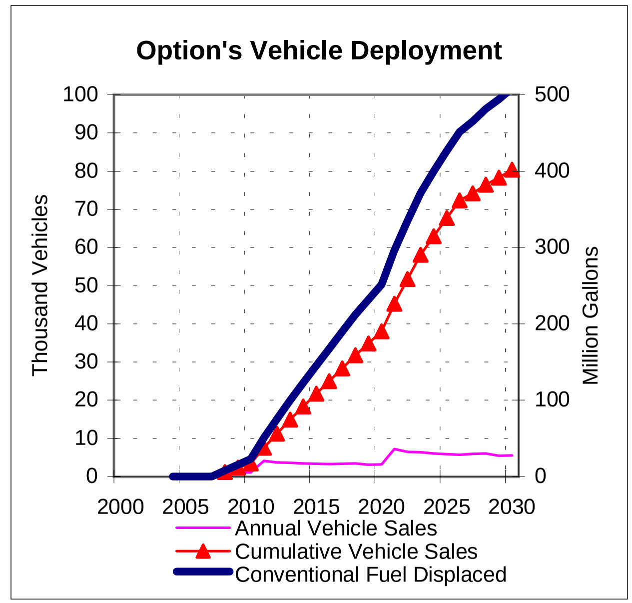
(The last five columns are headed "Fuel Displaced in Year Indicated".)

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$1.46	$1.53	($0.42)	($0.42)	$1.03	$1.11
2020	$1.50	$1.56	($0.42)	($0.42)	$1.08	$1.14
2030	$1.52	$1.57	($0.42)	($0.42)	$1.10	$1.15

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.65
Low Fuel Price Estimate ($/gallon)	$1.65
For This Option:	
Vehicle Fuel Economy (mi/gallon)	13.0
High Incremental Cost ($ per vehicle)	$9,375
Low Incremental Cost ($ per vehicle)	$5,625
High Fuel Price ($/Gallon)	$1.65
Low Fuel Price ($/Gallon)	$1.65
Vehicle Life (years)	16
Discount Rate (%)	5%



[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 1E-16

Summary of Analysis Results
Option 1E: More Efficient On-Road Medium- and Heavy-Duty Trucks

High Case, Class 7-8 Diesel Vehicles; Fuel Price: $1.82

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$52	$55	($14)	($14)	$38	$41
2002 to 2020	$1,309	$1,363	($336)	($336)	$974	$1,028
2002 to 2030	$3,546	$3,672	($897)	($897)	$2,649	$2,774

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$38	$39	($10)	($10)	$28	$30
2020	$421	$436	($106)	($106)	$315	$329
2030	$860	$886	($215)	($215)	$644	$671

Conventional Fuel Displaced (Million Gallons)

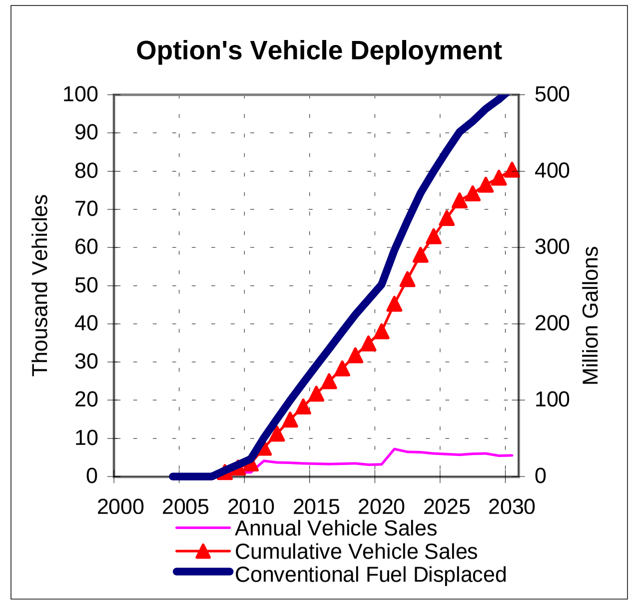
Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	468	468	2010	23	23	0.6%	0.6%
2002 to 2020	1,592	1,592	2020	251	251	6.0%	6.0%
2002 to 2030	5,823	5,823	2030	509	509	10.5%	10.5%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$1.63	$1.70	($0.42)	($0.42)	$1.20	$1.28
2020	$1.67	$1.73	($0.42)	($0.42)	$1.25	$1.31
2030	$1.69	$1.74	($0.42)	($0.42)	$1.27	$1.32

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.82
Low Fuel Price Estimate ($/gallon)	$1.82
For This Option:	
Vehicle Fuel Economy (mi/gallon)	13.0
High Incremental Cost ($ per vehicle)	$9,375
Low Incremental Cost ($ per vehicle)	$5,625
High Fuel Price ($/Gallon)	$1.82
Low Fuel Price ($/Gallon)	$1.82
Vehicle Life (years)	16
Discount Rate (%)	5%



[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Staff Paper on Option 1F
Light-Duty Diesel Vehicles

Description

This option examines the decreased use of gasoline when light-duty diesel vehicles (LDV) are substituted for gasoline vehicles.

Background

Because of its combustion characteristics, diesel fuel can be used in a compression ignition engine (commonly called a diesel engine). In practice, this type of engine has a potential energy efficiency that is greater than a gasoline fueled engine.

Information adapted from an assessment performed by the U.S. Department of Energy (DOE) comparing projected vehicle cost and fuel economy levels for different gasoline and diesel light-duty vehicle sizes is presented in Table 1F-1.[1] DOE believes that its various research and development programs for diesel engine technology can lead to the incremental vehicle prices and fuel economy levels shown in this table.[2] The incremental values include the cost difference between a diesel engine and a gasoline engine. The diesel engine technology used in the comparison was compression ignition, direct injection (CIDI). Although the baseline vehicle

Table 1F-1. Direct Injection Diesel Vehicles and Comparable Gasoline Vehicles

Vehicle Size	Fuel	1)Introduction Year 2) Maturity	Vehicle Price, $[a]	Diesel Incremental Price, $	Volumetric Fuel Economy Multiplier Compared to Gasoline[b]
Small Car	Diesel	1) 2003	17,300	1,100	1.40
		2) 2008	17,300	1,100	1.40
	Gasoline	1996	16,200	--	1.00
Large Car[c]	Diesel	1) 2005	27,200	1,800	1.35
		2) 2010	26,700	1,300	1.35
	Gasoline	1996	25,400	--	1.00
Sport Utility Vehicle	Diesel	1) 2004	25,100	1,800	1.45
		2) 2009	24,900	1,600	1.45
	Gasoline	1996	23,300	--	1.00
Minivan	Diesel	1) 2004	26,000	1,900	1.45
		2) 2009	25,800	1,700	1.45
	Gasoline	1996	24,100	--	1.00
Pickup Trucks, Large Vans	Diesel	1) 2002	18,100	1,700	1.35
		2) 2007	17,600	1,200	1.35
	Gasoline	1996	16,400	--	1.00

[a]The original 1996 costs were adjusted for inflation and brought to 2001$. A CEC factor, the GDP Implicit Price Deflator (1998 = 100), was applied to the 1996 vehicle costs. For this case, the factor was 1.0946 (106.23/97.05).
[b]The fuel economy improvement of the diesel vehicle includes the impact of satisfying the Tier II federal emission standards.
[c]The "Large Car" vehicle size includes intermediate sized vehicles.

used in the comparison was a 1996 model year vehicle in the size classes shown, the prices that are displayed in the table have been adjusted to 2001$.

The DOE advanced technology, light-duty diesel vehicles envisioned in Table 1F-1 are also targeted to meet the Tier II federal emission standards. The federal standards define emission performance levels in groupings of different emission levels of criteria pollutants over time. These groupings allow a manufacturer to place various vehicle models in different emission bins. Some of the emission bins correspond to the expected performance levels of California's LEV II categories of LEV, ULEV, SULEV, and ZEV. The federal standards differ by including emission bins that are not as stringent as California's LEV II categories in the near term and by requiring a fleet average threshold for NO_x instead of non-methane organic gases (NMOG). Over time, however, the federal system essentially merges with the LEV II categories. For this analysis, the Tier II technology diesel vehicle will be assumed to require additional emission control equipment to meet California LEV II standards beginning in model year 2007.

Status

Debate exists as to whether emission control technology can be developed to enable light-duty diesel vehicles to meet California's 2007 exhaust emission standards. Industry representatives have stated they will be able to develop satisfactory technology when used with expected low sulfur diesel (15 ppm sulfur), while public health advocates emphasize that no engines have been certified at this time and that future technologies and emission reductions are still uncertain. In the simplest terms, if manufacturers are unable to meet requirements, vehicles will not be sold. If current emission standards are found inadequate to protect health, they will be strengthened, and diesel technologies may or may not meet them.

Due to a variety of market constraints, light-duty diesel vehicles in California have historically experienced low sales when compared to gasoline vehicles. Table 1F-2 shows the relative market size and population of diesel vehicles in California for the vehicle classes used in this analysis.[3] With the exception of vans and heavier pickups (8,501 – 10,000 lbs. gross vehicle weight), the market share of 2000 model year diesel vehicles in these classes was less than 10 percent. Growth in diesel sales has not occurred in vehicle classes less than 8,500 pounds gross

Table 1F-2. Relative Vehicle Registrations of Selected Light-Duty Diesel Classes in California*

Vehicle Class	Percent of Class 2000 Model Year	Percent of Overall Light-Duty Fleet
Cars (compact, mid- & full-size)	0.1	4
Standard Pick Ups	0.8	1.1
Standard Vans	9.2	10
Standard Sport Utility	1.3	0.6
Pickups 8,501-10,000 lbs. GVW	35	22

*CEC DMV data SUM2000R3.XLS, Gary Occhiuzzo. CEC staff extracted DMV vehicle registration data for 2000 to produce the table values.

vehicle weight because they have been unable to comply with California emission standards. California's light-duty vehicle population, excluding commercial fleets, is currently near 20 million, and only about 300,000 vehicles are registered as diesel fueled.

Even though the current market for light-duty diesels in California seems very limited, policies in Europe and vehicle performance improvements have led to a much larger market share for diesels than in California.[4] The 2000 European LDV market share (annual sales) for diesel varies from about 10 percent in the United Kingdom to between 50 and 60 percent in France, Spain, and Austria.[5] Although the European experience may not be comparable to California due to different economic conditions and uncertainty regarding compliance with emission standards, the potential exists for consumers to choose an increasing proportion of diesel models over comparable gasoline models.

Market penetration analysis conducted by DOE for light-duty diesel vehicles using the vehicle classes with the attributes shown in Table 1F-1 shows an annual new vehicle market share peaking at about 20 percent by 2012.[6] This analysis employed input values based upon national market characteristics and would not necessarily model consumer response in California. If the incremental vehicle price used in their analysis assumed additional cost for emission control equipment, it is likely that their consumer choice model would project a lower market share.

Assumptions

The analysis of comparing a light-duty diesel vehicle with a gasoline counterpart requires the determination of a potential consumer cost difference between these two options. This incremental consumer cost (or savings) can then be weighed against the potential incremental benefits (or losses) of operating a diesel vehicle.

Based upon a 2002 market price comparison between a diesel Volkswagen Jetta and its gasoline counterpart, the vehicles' price difference, using the manufacturer's suggested retail price (MSRP), ranges between $1,050 to $1,295.[7] This price difference is similar to the estimate made by DOE for the small vehicle class meeting the Tier II federal emission standards for light-duty vehicles.[8]

With the exception of the 2007 particulate matter and NO_x standards, the 2002 diesel Jetta could meet California's LEV II standards for the other criteria pollutants. Thus, it may be reasonable to assume that with low sulfur diesel fuel and the use of a combination of engine re-calibration and additional control for particulates (e.g., a catalyzed particulate filter) and NO_x (e.g., a NO_x adsorber), this vehicle could achieve LEV II performance. The cost (or price) to achieve this incremental emission improvement would then be added to the current MSRP incremental to derive an incremental vehicle price for a hypothetical California LEV II diesel vehicle.

Technologies are now being developed and evaluated as potential emission control measures for advanced diesel engines. For the purpose of this analysis, estimates of the additional cost due to these technologies have been extrapolated from projected costs made by the U.S. Environmental Protection Agency (EPA) for heavy-duty vehicles.[9] The relative size of key emission control components, e.g., the NO_x adsorber and catalyzed particulate filter, were determined to be scaled to engine displacement. Thus, the relative cost of these components can also be related to engine size.

The EPA's estimates of diesel vehicle incremental price due to emission control additions were for light-heavy, medium-heavy, and heavy-heavy diesel trucks. These truck classes were assumed to typically use engines with displacements of 6, 8, and 13.3 liters, respectively. The diesel engine sizes that are likely to be found in a light-duty vehicle range from 2 to 6 liters. The incremental emission control costs (consumer prices) for the light-duty vehicles were extrapolated from the larger engine estimates. The near-term (2007) and long-term (2012+) incremental prices for emission controls are summarized in Table 1F-3.

Table 1F-3. Price Estimates for Diesel Emission Controls (2001$)*

Engine Displacement (liters)	NOx Adsorber		Catalyzed Particulate Filter		Miscellaneous Components		Total	
	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term	Near Term	Long Term
2	640	407	382	235	128	78	1,150	695
3	721	459	466	287	160	99	1,347	845
4	802	511	551	339	191	120	1,544	970
5	884	563	635	391	222	141	1,741	1,096
6	965	618	720	443	254	162	1,939	1,223
8	1,127	721	889	550	316	202	2,332	1,473
13.3	1,519	972	1,151	716	404	259	3,074	1,947

*Values for 6-13.3 liters taken from U.S. EPA, Regulatory Impact Analysis: Heavy Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, December 2000, Air and Radiation, EPA420-R-00-026, December 2000. Values for 2-5 liters were extrapolated from the larger engine sizes. All values adjusted from 1999$ to 2001$ using the CEC GDP Implicit Price Deflator factor of 1.043 (106.23/101.81, 1998=100). Near Term is 2007. Long Term is 2012+.

The scaling method used is likely to result in price estimates that are higher than actual prices because the driving cycle and durability constraints for heavy-duty vehicles are more severe than for light-duty applications. Thus, the analysis may over predict the cost impact of additional emission controls. For the non-environmental elements considered in the cost-benefit comparison with an average gasoline vehicle, this over-prediction in consumer cost results in lower estimates of consumer and net benefits. The degree of this impact, however, is not clear.

Since the potential displacement of gasoline with diesel is based upon a comparison with an average gasoline vehicle (a vehicle with an average fuel economy projected by the CALCARS model, 21.2 mpg gasoline), the key parameters of an average light-duty diesel vehicle must also be defined. This involves a determination of typical engine size, incremental prices for emission controls linked to engine size, and vehicle fuel economy.

An estimate of average engine size for light-duty vehicles is made by considering the listed vehicle models and engine combinations in the U.S. EPA Fuel Economy and Certification Guide. An average engine displacement certified for sale by vehicle class can be calculated and matched to the vehicle classes used in the DOE analysis.[10] This would allow the matching of the estimated vehicle incremental price to engine size. Results from this estimation are displayed in Table 1F-4, Columns A-D.

The determination of engine displacements that correspond to the vehicle classes considered in Table 1F-4 allows one to make an estimate for the incremental prices related to additional emission controls for LEV II compliance within those classes. These incremental prices for emission controls are interpolated from Table 1F-3. The results for this estimation are displayed in Table 1F-4, Column F. By combining the incremental prices for the vehicle classes shown in Column E and for the vehicle emission controls in Column F, a total incremental price is calculated (Column G).

Table 1F-4. Estimated Incremental Vehicle Price for Light-Duty Diesel Vehicles, Long-Term (2012+) and Near-Term (2007)

A	B	C	D	E	F		G =E+F	
U.S. EPA Vehicle Class	**Average Engine Size[a] (liters)**	**DOE Quality Metrics Vehicle Class**	**Average Engine Size Binned to DOE Vehicle Class (liters)**	**DOE Quality Metrics, Diesel vs. Gasoline, Incremental Vehicle Prices (2001$)**	**Estimated Incremental Emission Control Price[b] (2001$)**		**Total Estimated Incremental Vehicle Price, LEV II (2001$)**	
					Long	**Near**	**Long**	**Near**
Minicompact	2.5	Small	2.5	1,100	780	1,250	1,880	2,350
Subcompact	2.6							
Compact	2.4							
Mid-size	3.0	Large	3.6	1,300	920	1,470	2,200	2,770
Large	4.2							
Small Pickup	3.0	Pickups, Large Vans	4.3	1,200	1,000	1,600	2,200	2,800
Standard Pickup	4.3							
Cargo Van	4.9							
Passenger Van	4.8							
Minivan	3.3	Minivans	3.3	1,700	880	1410	2,580	3,110
SUV	3.4	SUVs	3.4	1,600	900	1430	2,500	3,030

	Long Term	Near Term
Average Incremental Vehicle Price, Pickups & SUVs ($ rounded)	2,400	2,900
Average Incremental Vehicle Price, Small, Large, & Minivans ($ rounded)	2,200	2,700

[a]Average of engine sizes listed in the U.S. EPA Fuel Economy and Certification Guide, 1999.
[b]Values interpolated and rounded from Table 1F-3.

For the average diesel vehicle evaluated in this option, the projected fuel economy improvement over a comparable gasoline vehicle was determined by considering estimates from DOE,[11] values provided by diesel engine and vehicle manufacturers for current diesel offerings or experimental results (Table 1F-5), and the impact of future emission controls on fuel economy. According to an estimate from the Argonne National Laboratory, a 3 percent fuel economy penalty can be assumed for a California specific diesel vehicle compared to a non-California diesel.[12]

From the data that has been gathered, the range of estimated fuel economy improvement for a light-duty diesel, expressed as a fuel economy multiplier, is 1.35 to 1.56. Staff assumed that the average light-duty diesel vehicle will likely have a fuel economy improvement range bounded by these values. Since actual on-road fuel economy can be less than certification or experimental test results, the value that is used in the comparison analysis is 1.45, weighted toward the values estimated by DOE.

Table 1F-5. Diesel and Gasoline Vehicle Fuel Economy Comparisons

Model Year	Make/Model (Class)	Fuel Type	Fuel Economy (mpg) City	Fuel Economy (mpg) Highway	Fuel Economy (mpg) Combined	Combined Fuel Economy Improvement Compared to Gasoline (%)
2001	VW/Golf/ New Beetle (Small Car)[a]	Diesel	34	44	37.9	49
		Gasoline	23	29	25.4	N/A
2002	VW/Jetta/Golf (Small Car)[a]	Diesel	34	45	38.2	50
		Gasoline	23	29	25.4	N/A
Experimental	Dodge Durango Cummins/DOE Repower (SUV)[b]	Diesel	20.2	25.0	22.1	60
2001	Dodge Durango 4x4 (SUV)[b]	Gasoline	12.0	17.0	13.8	N/A
Experimental	Dodge Ram 1500 Cummins/ DOE Repower (Pickup)[b]	Diesel	19.8	24.6	21.7	61
2001	Dodge Ram 1500 4x4 (Pickup)[b]	Gasoline	12	16	13.5	N/A
2000	Ford Excursion (SUV)[c]	Diesel	15	18	16.2	45
2000	Ford Excursion (SUV)[c]	Gasoline	10	13	11.2	N/A

[a] Source: US EPA Fuel Economy and Certification Guides.
[b] Source: Cummins Engine Company.
[c] Source: International Truck and Engine Corporation.

Staff assumed that highly efficient NO_x and particulate matter (PM) after-treatment will be available and used on light duty diesel vehicles beginning in 2007, allowing a growth in sales to occur. Low sulfur diesel fuel will also be available in mid-2006, as currently required by the EPA.

Based upon the results of a 1998-1999 survey of about 7,500 retail service stations in California, the existing retail infrastructure for dispensing diesel is assumed to be adequate for the projected growth in diesel vehicle population during the initial years for the scenario evaluated.[13] The survey found that about 24 percent of the sites dispensed diesel fuel. For additional infrastructure beyond this level, the cost of expanding retail fuel stations to dispense diesel is assumed to be absorbed by private industry as a normal investment option, controlled by the economic opportunity of supplying diesel fuel to meet demand. The diesel fuel price used in the analysis includes a retail margin that would normally pay for infrastructure expenses.
Table 1F-6 shows the values for key parameters that will produce upper and lower bound cases.

Table 1F-6. Selected Light-Duty Diesel Vehicle Parameters Compared to Gasoline Vehicle

Diesel Incremental Vehicle Price* (2001$) Long Term, 2012+ Low	Long Term, 2012+ High	Near Term, 2007 Low	Near Term, 2007 High	Diesel Volumetric Fuel Economy Multiplier	Gasoline Vehicle Fuel Economy (mpg)
2,200	2,400	2,700	2,900	1.45	21.2

*The values do not reflect potential market conditions or dealer pricing decisions.

A vehicle ownership comparison between diesel and gasoline vehicles is conducted assuming the incremental price ranges and other key parameters shown in Table 1F-6. The diesel vehicle modeled would have a volumetric fuel economy of about 30.7 mpg. A discount rate of 5 percent was used to determine consumer costs and benefits.

Beginning in 2008, the average diesel vehicle with the near-term incremental price range begins to penetrate the fleet population. The annual new vehicle sales rate was assumed to be less than one percent of new light-duty vehicles in 2008 and ramping up to about 10 percent by 2020. From 2008 to 2012, the incremental vehicle price linearly declines to the long-term range and is constant thereafter. The diesel vehicle sales rates used in this scenario are not a prediction of specific market penetration.

The estimate for petroleum fuels reduction is based on the assumption that diesel vehicles meeting 2007 California emission standards would begin to be marketed in 2008. This assumption is being made for comparison purposes with other fuel substitution options.

Although some data indicates that a diesel vehicle depreciates at a lower rate compared to a gasoline vehicle, the data was limited to a five-year period and for a single vehicle model.[14] Applying this information to the average light-duty diesel vehicle would be premature. Thus, both diesel and gasoline vehicles are assumed to depreciate at the same rate.

Diesel and gasoline fuel prices that were projected for the base case energy demand forecast were used with a standard deviation of $.17 per gallon, based upon historical monthly price variations.

Results

Tables 1F-7 to 1F-9 display the results of the analysis for gasoline reduction from light-duty diesel vehicles. When only capital and fuel expenses are considered for the average diesel and gasoline vehicles modeled, average consumers can expect to be better off when owning and operating an “average” diesel vehicle over a 15-year life compared to an equivalent gasoline vehicle. This result appears in the Consumer Benefits columns under the Present Value section for the periods 2002 to 2020 and 2002 to 2030. Present value of consumer benefits range from about $12 to $360 million for the period 2002 to 2020 and $459 million to $1.6 billion for the period 2002 to 2030. Savings in fuel costs will be greater over the vehicle’s lifetime than the incrementally higher cost of purchasing the diesel vehicle. However, consumers who do not drive as much as the average consumer or sell their vehicle sooner may not recover the incremental vehicle cost. For example, since the deployment modeled does not begin until 2008, the vehicle ownership and operational period is relatively short for the present value period of 2002 to 2010, producing a consumer “cost” (loss) over this period.

Since the fuel economy of the diesel is greater than a comparable gasoline vehicle, government revenue from fuel excise taxes would decline if greater numbers of diesel vehicles became part of the light-duty fleet population. This is shown in the Change in Government Revenue columns. The revenue loss is estimated to be about $104 million (present value) for the period 2002 to 2020 and $349 million for the period 2002 to 2030.

When the consumer impact is combined with the government revenue impact, a Net Benefit (present value) can be projected under certain fuel price conditions and time periods. At the lowest gasoline comparison price of $1.47 per gallon, the net benefit ranges from a loss of about $2 to $92 million for the period 2002 to 2020 or a savings from $110 to $380 million for the period 2002 to 2030. At the highest gasoline comparison price of $1.81 per gallon, the net benefit ranges from a savings of about $37 to $127 million for the period 2002 to 2020 or $546 to $816 million for the period 2002 to 2030.

These benefit trends indicate a positive consumer and net benefit outcome for the light-duty diesel option, especially for long-term application.

When the costs are evaluated for individual years, similar results are seen. In 2010, consumers would lose $3 to $6 million at gasoline prices of $1.81 to $1.47 per gallon, respectively. Government revenue would decline about $1 million. Net losses would total about $4 to $7 million. Consumer benefits are positive in 2020 and 2030. In 2020, consumers would save $$36 to $191 million at gasoline prices of $1.47 and $1.81 per gallon, respectively. Government revenue declines by about $47 million and $98 million in 2020 and 2030, respectively. In 2030, consumer benefit would be about $244 to $311 million or $367 to $434 million at gasoline prices of $1.47 and $1.81 per gallon, respectively. Net benefits range from a loss of $11 million in 2020 at $1.47 per gallon gasoline to a savings of up to $335 million in 2030 at $1.81 per gallon gasoline. These benefit and revenue values are not expressed as present values.

For the scenario modeled, the annual amounts of gasoline displaced in 2020 and 2030 are about 5.7 percent and 10.4 percent of the base case demand, respectively. Although the volume of gasoline displaced seems large due to the replacement of a gasoline vehicle by a diesel vehicle, an equally important value is the growth in diesel fuel consumption. In 2020 and 2030, annual diesel fuel consumption would increase by 19.2 percent and 35.1 percent over the base case, respectively. The annual net volumes of petroleum fuel reduction (combined gallons of gasoline displaced and diesel fuel increase) in 2020 and 2030 are 1.5 percent and 2.6 percent, respectively (equivalent to 0.8 percent and 1.4 percent on an energy content basis).

Although the fuel comparison in this analysis is between petroleum-based gasoline and diesel, the diesel engine can also use alternative fuels such as biodiesel and Fischer-Tropsch diesel. Using such fuels in light-duty diesel vehicles could further reduce the consumption of petroleum based fuels. If these alternatives were available, the projected growth in conventional diesel fuel demand would be lower and any projected growth in diesel fuel demand could be neutralized. There may also be some additional environmental benefits that would result from the use of these non-petroleum based diesel fuels.

In the long-term, 2020 to 2030, this option can displace the use of gasoline at a benefit (savings) to consumers. For example, in 2030 the consumer benefit per gallon of gasoline displaced ranges from a savings of $0.10 to $0.19. The net benefit per gallon of gasoline displaced ranges from $0.06 to $0.14.

Key Uncertainties

- There is uncertainty regarding California consumer response to light duty diesel vehicles under 8,500 lbs. gross vehicle weight. Logically, if other vehicle characteristics and performance levels were equal, the higher vehicle cost for a diesel would have to be defrayed by its fuel savings to persuade a large fraction of consumers to choose a diesel over a gasoline vehicle. Future gasoline vehicles may also improve their fuel economy, partially offsetting a diesel vehicle's operating cost advantage and reducing its attractiveness.

- Corporate average fuel economy (CAFE) regulations may be revised to compel vehicle manufacturers to produce higher fuel economy for standard and compact pickup trucks. To take advantage of their higher fuel economy, manufacturers may offer additional vehicle models with diesel engines.

- For light duty vehicles with a gross vehicle weight of less than 8,500 pounds, most of which are passenger-carrying vehicles, emission regulations for HC, CO, and NO_x have been set based on the lowest achievable emission rate for gasoline vehicles. For diesel engine light duty vehicles to achieve such emissions standards, highly efficient exhaust after-treatment for both NO_x and PM is required.[15]

- A significant increase in diesel product demand may require changes to California refineries which are generally designed to maximize their gasoline production or greater volumes of diesel fuel will need to be imported to California. Diesel production is directly limited by the capacity of desulfurization units such as hydrotreaters, hydro-desulfurization units and fluid catalytic crackers.

- Other supply options that could support a larger population of light-duty diesel vehicles include greater use of synthetic fuels such as Fischer-Tropsch diesel for in-state blending and greater imports of refined diesel meeting CARB fuel specification (e.g., EPA diesel blended with Fischer-Tropsch diesel). These options may be less expensive compared to the cost of increasing the state's supply of diesel fuel derived from petroleum.

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[1] U.S. Department of Energy, Program Analysis Methodology, Office of Transportation Technologies, ***Quality Metrics Final Report 2001***, February 23, 2000.

[2] Personal communication between Dan Fong (CEC) and Philip Patterson, U.S. DOE, Office of Transportation Technologies, June 21, 2002.

[3] CEC DMV data SUM2000R3.XLS, Gary Occhiuzzo. DMV vehicle registration data for 2000 was extracted by CEC staff to produce the table values.

[4] Such policies include, for example, high taxation rates on fuels, favorable fuel taxation on diesel fuel versus gasoline, and different exhaust emission standards.

[5] Ward's Auto World, Super Diesels, The Market, figure on page 39, September 2001.

[6] U.S. Department of energy, Program Analysis Methodology, Office of Transportation Technologies, Quality Metrics Final Report 2001, February, 23, 2000.

[7] http://auto.yahoo.com/newcars/details/volkswagen02jetta/index.html, May 16, 2002.

[8] U.S. Department of Energy, Program Analysis Methodology, Office of Transportation Technologies, ***Quality Metrics Final Report 2001***, February 23, 2000.

[9] U.S. EPA, ***Regulatory Impact Analysis: Heavy Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements***, December 2000, Air and Radiation, EPA420-R-00-026, December 2000.

[10] U.S. Department of Energy, Program Analysis Methodology, Office of Transportation Technologies, ***Quality Metrics Final Report 2001***, February 23, 2000.

[11] U.S. Department of Energy, Program Analysis Methodology, Office of Transportation Technologies, ***Quality Metrics Final Report 2001***, February 23, 2000.

[12] Personal communication between Gary Yowell (CEC) and Frank Stodolsky, Argonne National Laboratory, March 14, 2002. For modeling purposes, a 3 percent fuel economy penalty is assumed to be required due to emission controls estimated to meet California emission standards.

[13] CEC used proprietary contractor survey data on about 75 percent of all California retail service stations in 1998-99 and found that about 24 percent of these sites dispensed diesel fuel. These sites were concentrated in cities and urban counties. Thus, the existing accessibility of diesel fuel is not assumed to limit the market growth for diesel vehicles.

[14] Gretchen Knudsen, International Truck and Engine Corportation, letter to Dan Fong, November 11, 2002

[15] PM filters have demonstrated the efficiency needed to comply with the California PM standard for light duty diesels, and these filters are being used on some new diesel passenger cars sold in Europe. The greater challenge for diesel vehicles is the development of NOx after-treatment which is durable and of high enough efficiency to comply with the California NOx standard. Development efforts are focused on heavy-duty engines, which will require NOx after-treatment beginning in 2007. Similar technology can be used on light-duty diesel vehicles. For vehicles with gross vehicle weights in excess of 8,501 pounds, which include many work trucks, emissions standards are more closely tied to the standards for heavy-duty truck engines. This has resulted in emissions standards for heavier pickups and delivery vehicles that can be more readily met by using diesel engines, as evidenced by the substantial number of diesel vehicles being sold in this weight class.

Table 1F-7

Summary of Analysis Results
Option 1F: Light-Duty Diesel Vehicles

Fuel Price: $1.47

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($7)	($6)	($1)	($1)	($9)	($7)
2002 to 2020	$12	$101	($104)	($104)	($92)	($2)
2002 to 2030	$459	$729	($349)	($349)	$110	$380

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($6)	($4)	($1)	($1)	($7)	($6)
2020	$36	$74	($47)	($47)	($11)	$27
2030	$244	$311	($98)	($98)	$146	$212

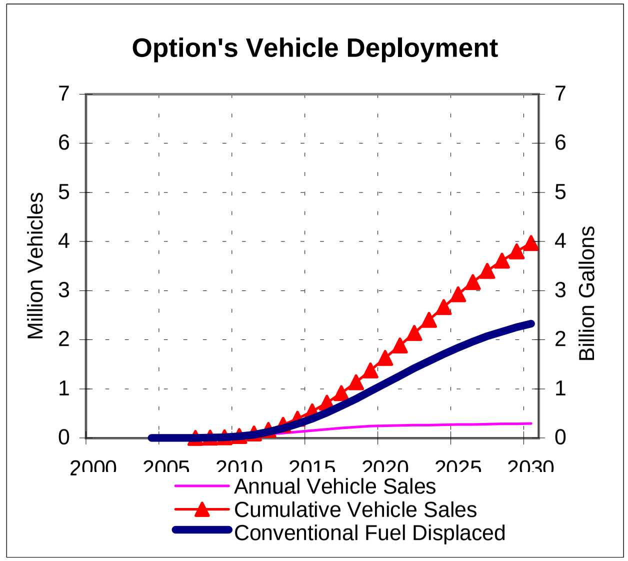
MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.47
Low Fuel Price Estimate ($/gallon)	$1.47
For This Option:	
Vehicle Fuel Economy (mi/gallon)	30.7
High Incremental Cost ($ per vehicle)	$2,400
Low Incremental Cost ($ per vehicle)	$2,200
High Fuel Price ($/Gallon)	$1.48
Low Fuel Price ($/Gallon)	$1.48
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	46	46	2010	31	31	0.2%	0.2%
2002 to 2020	5,139	5,139	2020	1,111	1,111	5.7%	5.7%
2002 to 2030	23,713	23,713	2030	2,327	2,327	10.4%	10.4%

(Low/High/Low %/High % under "Fuel Displaced in Year Indicated")



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.19)	($0.15)	($0.04)	($0.04)	($0.24)	($0.19)
2020	$0.03	$0.07	($0.04)	($0.04)	($0.01)	$0.02
2030	$0.10	$0.13	($0.04)	($0.04)	$0.06	$0.09

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 1F-8

Summary of Analysis Results
Option 1F: Light-Duty Diesel Vehicles

Fuel Price: $1.64

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($6)	($4)	($1)	($1)	($7)	($5)
2002 to 2020	$141	$231	($104)	($104)	$37	$127
2002 to 2030	$895	$1,165	($349)	($349)	$546	$816

Single Year Savings in Millions of 2001 Dollars

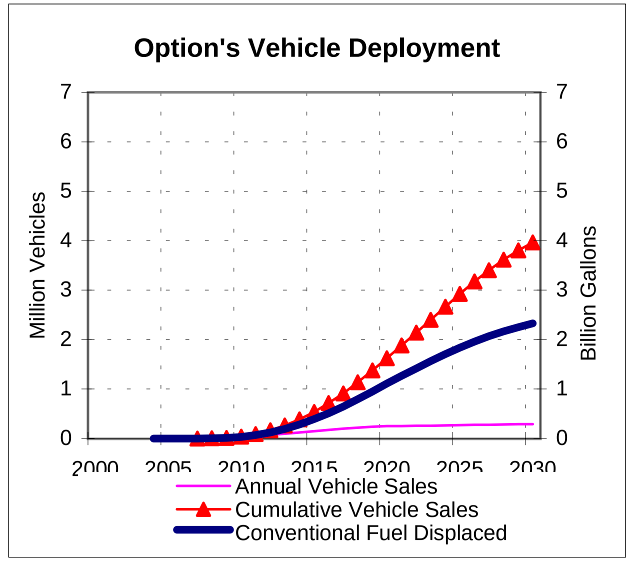
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($4)	($3)	($1)	($1)	($6)	($4)
2020	$94	$133	($47)	($47)	$47	$86
2030	$367	$434	($98)	($98)	$268	$335

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.64
Low Fuel Price Estimate ($/gallon)	$1.64
For This Option:	
Vehicle Fuel Economy (mi/gallon)	30.7
High Incremental Cost ($ per vehicle)	$2,400
Low Incremental Cost ($ per vehicle)	$2,200
High Fuel Price ($/Gallon)	$1.65
Low Fuel Price ($/Gallon)	$1.65
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
			Fuel Displaced in Year Indicated				
2002 to 2010	46	46	2010	31	31	0.2%	0.2%
2002 to 2020	5,139	5,139	2020	1,111	1,111	5.7%	5.7%
2002 to 2030	23,713	23,713	2030	2,327	2,327	10.4%	10.4%



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.14)	($0.09)	($0.04)	($0.04)	($0.18)	($0.13)
2020	$0.08	$0.12	($0.04)	($0.04)	$0.04	$0.08
2030	$0.16	$0.19	($0.04)	($0.04)	$0.12	$0.14

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 1F-9

Summary of Analysis Results

Option 1F: Light-Duty Diesel Vehicles

Fuel Price: $1.81

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($4)	($2)	($1)	($1)	($5)	($4)
2002 to 2020	$270	$360	($104)	($104)	$167	$256
2002 to 2030	$1,330	$1,600	($349)	($349)	$981	$1,251

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($3)	($1)	($1)	($1)	($4)	($3)
2020	$153	$191	($47)	($47)	$106	$144
2030	$490	$556	($98)	($98)	$391	$458

Conventional Fuel Displaced (Million Gallons)

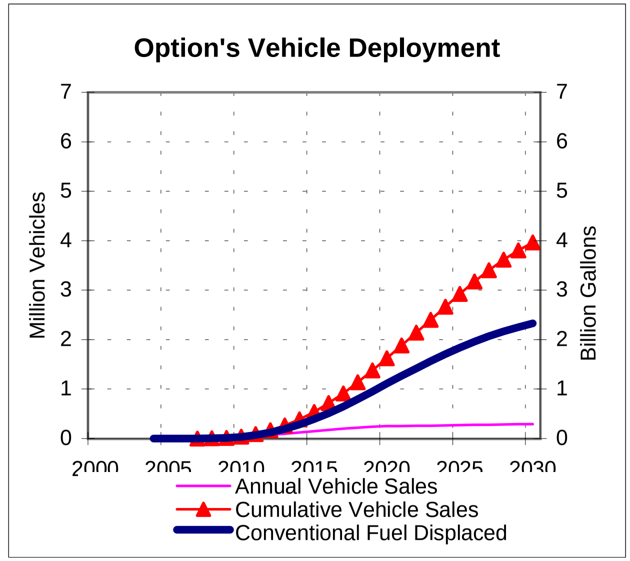
Cumulative Over Time Period			Fuel Displaced in Year Indicated				
	Low	High	Year	Low	High	Low %	High %
2002 to 2010	46	46	2010	31	31	0.2%	0.2%
2002 to 2020	5,139	5,139	2020	1,111	1,111	5.7%	5.7%
2002 to 2030	23,713	23,713	2030	2,327	2,327	10.4%	10.4%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.09)	($0.04)	($0.04)	($0.04)	($0.13)	($0.08)
2020	$0.14	$0.17	($0.04)	($0.04)	$0.10	$0.13
2030	$0.21	$0.24	($0.04)	($0.04)	$0.17	$0.20

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.81
Low Fuel Price Estimate ($/gallon)	$1.81
For This Option:	
Vehicle Fuel Economy (mi/gallon)	30.7
High Incremental Cost ($ per vehicle)	$2,400
Low Incremental Cost ($ per vehicle)	$2,200
High Fuel Price ($/Gallon)	$1.82
Low Fuel Price ($/Gallon)	$1.82
Vehicle Life (years)	15
Discount Rate (%)	5%



[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Staff Paper on Option 2A
Fuel Cells

Description

This option assumes that with considerable industry effort and government assistance, fuel cell vehicles realize a significant penetration in California's light-duty vehicle market by 2030.

Background

Fuel cell vehicles (FCVs) hold the promise of high efficiency, zero or near-zero tail pipe emissions, and little or no evaporative emissions depending on the fuel type used. FCVs have the potential for significantly better fuel economy than conventional internal combustion engine (ICE) vehicles. When operating on direct hydrogen, fuel cell vehicles produce no tail pipe emissions, only water and heat.

Like batteries, fuel cells provide electricity through an electrochemical reaction. However, fuel cells do not require electric recharging. Fuel cell vehicles and battery electric vehicles are sometimes called "electric drive vehicles" because they utilize an electric motor rather than an internal combustion engine (ICE).

All fuel cells operate on hydrogen, which can be stored on-board the vehicle (direct) or produced on-board the vehicle from a hydrocarbon fuel with a reformer (indirect). Leading candidate fuels under consideration for onboard reforming include gasoline, methanol and ethanol.

Concerns continue over which fuel will be used as a source of hydrogen and who will pay for FCV infrastructure development. If an appropriate fueling infrastructure is not deployed in a timely manner and with convenient access, market development for FCVs may be severely constrained. In the case of direct hydrogen FCVs, the cost of hydrogen station development can be several times higher than existing gasoline stations. If gasoline is to be utilized in FCVs, either the gasoline will need to be modified (i.e., refined to ultra-low sulfur levels), or gasoline reformers must improve to handle today's gasoline designed for internal combustion engines. In the long-term, the preferred fuel is hydrogen because of its superior environmental and potential energy benefits.

While ethanol could be used as a hydrogen source for FCVs, supply uncertainties for ethanol would have to be addressed given existing ethanol production plans. Staff is unaware of any automobile manufacturers pursuing an ethanol FCV option. Furthermore, prices for ethanol are expected to be higher on a cost per mile basis than other fuels considered here. If ethanol were to be utilized by FCVs it could potentially be used either in a neat feedstock (E100) or blended with gasoline (i.e., E10, E20, etc.) with petroleum savings corresponding to the blend level and efficiency gains - expected to be comparable to gasoline reformers.

Status of Fuel Cell Vehicles

A few dozen light-duty FCVs are now being demonstrated around the world, notably in California under the auspices of the California Fuel Cell Partnership. Numerous automobile manufacturers are devoting substantial resources toward the development of FCVs, with the hope that over the long-term the capital cost of various fuel cell technologies will become cost competitive with the gasoline ICE vehicle, as well as other competing technologies. However, this technology is pre-commercial and the likelihood of achieving substantial market penetration is uncertain. The timing, cost and durability of fuel cell technologies are all challenges that are being addressed by stakeholders.

Fuel cell vehicles are at an early stage in their development, with significant hurdles to overcome. Nevertheless, the vehicles show good potential and both government and private stakeholders are devoting large resources to overcome these hurdles. This process, however, will take time. With current development progress, only a relatively small number of noncommercial FCVs are likely to be operating by 2010. For light-duty FCVs to achieve significant sales levels by 2012, major technical and economic breakthroughs for fuel cells need to occur no later than 2008. These breakthroughs would include improving fuel cell stack performance and reliability, improving reformer technology, significantly reducing costs for these systems, and improving hydrogen storage systems for direct hydrogen fuel cell vehicles. For example, to be competitive with gasoline ICE technology, the cost of fuel cells per kilowatt (kW) will need to drop several times from the current amount to about $45/kW (which matches the U.S. Department of Energy's goal).

In the near-term, FCVs will be costly for manufacturers to produce and sell and for owners to operate. Costs are assumed to be high compared to conventional gasoline vehicles, but falling as technology improves at a rapid pace. For example, Arthur D. Little, Inc. estimates the incremental cost for FCVs during the 2010-2020 time period to be approximately $9,000 to$11,000 per vehicle.[1] Compared to current conventional gasoline ICE vehicles, intermediate-term market direct hydrogen FCVs that meet development goals could have 1.8 to 3.0 times higher equivalent fuel economy. Methanol steam reforming (SR) hybrid fuel cell vehicles could have 1.2 to 1.7 times higher fuel economy. Gasoline or ethanol hybrid auto-thermal reforming (ATR) fuel cell vehicles could have 1.1 to 1.6 times higher fuel economy.

The U.S. Department of Energy (DOE) spent $36.6 million on fuel cell vehicle research and development (R&D) in fiscal year (FY) 2000, $41.3 million in FY 2001, and requested $41.9 million for FY 2002. Correspondingly, they requested $8.7 million for electric drive vehicle (battery) R&D in FY 2000. DOE requested $9.0 million in FY 2001 and $3.5 million for FY 2002.[2] Federal FCV R&D focuses on lowering fuel cell stack and reformer component costs, improving fuel processor performance targets, integrating system components, and reducing costs for onboard hydrogen storage.

FreedomCAR Program. In January 2002, the US DOE announced a new initiative to promote the advancement of hydrogen and FCVs. Called FreedomCAR (for Cooperative Automotive Research), this program replaced the Partnership for a New Generation of Vehicles (PNGV) program established in September 1993. The FreedomCAR program is a public-private partnership between DOE and Ford, General Motors and DaimlerChrysler that promotes the development of hydrogen as a primary fuel for cars and trucks.

The program focuses on research needed to develop technologies such as fuel cells and hydrogen from domestic renewable sources. FreedomCAR also will focus on technologies to enable mass production of affordable hydrogen-powered fuel cell vehicles and the hydrogen-supply infrastructure to support them.[3]

Table 2A-1. DOE Research and Development Goals for Fuel Cell Vehicles[4]
(50-kW integrated fuel cell power systems operating on Tier 2 gasoline containing 30 ppm sulfur.)

	Durability (hours)	Energy Efficiency at 25% Peak Power	Cold Start @ 20C° to Maximum Power (minutes)	Power Density (watts/liter)	Specific Power (watts/kg)	Cost ($/kW)
Status 2001	1000	34%	<10.0	140	140	300
2005 Goal	2000	40%	<1.0	250	250	125
2010 Goal	5000	45%	<0.5	325	325	45

The program will focus on the research needed to develop technologies such as fuel cells and hydrogen from domestic, renewable sources. FreedomCAR also will focus on technologies to enable mass production of affordable hydrogen-powered fuel cell vehicles and the hydrogen-supply infrastructure to support them.[5]

FCV Challenges. Reducing the fuel cell stack cost and improving durability are key challenges that must be resolved before fuel cell vehicles can become competitive with current vehicle technologies. Other technical issues include fuel cell stack performance, balance of plant improvements (necessary supporting components), cold temperature operation, reformer development, hydrogen storage technology and others.[6]

Direct hydrogen FCVs must be able to store enough fuel to provide an adequate driving range (e.g., 300 or more miles). FCVs operating on direct hydrogen will most likely have a limited driving range in the near- and mid-term, because of the fuel’s comparably poor energy density.

Hydrogen fuel tanks with higher pressures, such as 5,000 psi systems, do help with extending driving range and appear to be common in today’s prototype FCVs, but further improvements are needed. While the industry is currently testing fuel tanks with even higher pressures (i.e., 10,000 psi), even this may not be a viable answer long-term as on-board fuel supply does not proportionally correspond to higher tank pressures. Furthermore, higher compression pressures require additional energy inputs, which result in higher costs. Other storage systems, such as chemical or metal hydrides and carbon nanotubes are being worked on, but it remains unclear which storage technology will succeed in the long-term.

Hydrogen can also be stored in its liquid state. Liquid hydrogen provides improved energy density and therefore increase driving range, but is more costly and poses unique challenges. Disadvantages include higher energy inputs, required cryogenic station storage, dispensing equipment and vehicle tanks, as well as the loss of hydrogen over time through "boil off," a natural loss of fuel as the temperature rises from its -423^{o}F liquid state.

Staff assumed that in a mature market, hydrogen FCVs will operate on compressed gas and will provide a driving range that is competitive with other vehicle technologies.

Hydrogen Safety. Hydrogen is sometimes viewed as a dangerous fuel to store and handle. Like all other fuels, hydrogen can be dangerous when the proper precautions are not in place. While codes and standards are in place, some need revision to provide for hydrogen use as a transportation fuel. Consequently, significant resources are now being devoted to this issue, both by government agencies and by industry, to ensure safety is not compromised.

Hydrogen Production. During the period of the report, staff assumed that natural gas will be the primary feedstock for hydrogen production, as it is today. Ultimately, however, renewable fuels are viewed as a sustainable and environmentally preferred source of hydrogen production. Renewable sources of hydrogen reduce or eliminate the production of regulated pollutants, as well as greenhouse gas emissions. Sources include electrolysis utilizing solar, wind, hydroelectric power, etc. Additionally, biomass, such as agricultural and forest residues, can also be converted to hydrogen through gasification.

Hydrogen as a transportation fuel will likely be more expensive than other FCV fuels both in the near- and long-term. Because hydrogen generally does not exist on its own, it must be produced from other sources (e.g., natural gas, petroleum, etc., or water via electrolysis), and requires sizable energy inputs. Furthermore, the cost of compressing and transporting hydrogen is costly because of its modest energy density and other factors.

While initial hydrogen stations will be costly, the high volumes expected of FCVs over the long-term will create significant fuel demand and should lead to lower station costs and ultimately lower retail hydrogen prices.

Assumptions and Methodology

Two fueling categories are evaluated below for light-duty fuel cell vehicles:

- Non-petroleum - Vehicles that are fueled from a non-petroleum source, either hydrogen (direct), alcohol fuel (indirect, where hydrogen is produced from an onboard reformer) or a combination of the two fuels.

- Petroleum-based - Vehicles that are fueled with a petroleum-based hydrocarbon fuel (likely gasoline used with an onboard reformer), which offer improved vehicle efficiency over conventional gasoline ICE vehicles, but of course displace much less petroleum.

Mature Market. Compared to current conventional gasoline ICE vehicles, mature market direct hydrogen FCVs that meet development goals could have 2.0 to 3.5 times higher equivalent fuel economy. Methanol steam reforming (SR) hybrid fuel cell vehicles could have 1.2 to 1.9 times higher fuel economy. Gasoline or ethanol hybrid auto-thermal reforming (ATR) fuel cell vehicles could have 1.2 to 1.7 times higher fuel economy. Because these fuel economy levels are uncertain, the following analyses employ nominal equivalent fuel economy factors of 2.5, 1.7, and 1.5, for direct hydrogen, methanol steam reforming, and gasoline reforming, respectively.

Most of the Group 2 (Fuel Substitution) options assume that vehicle deployment will begin in 2008. Due to the very early status of fuel cell vehicle development, however, it does not appear likely that this schedule could be met with fuel cell vehicles. Therefore, staff assumed for fuel cell vehicles that vehicle deployment begins in 2012.

Hydrogen Prices. Future estimates for the price of hydrogen for FCVs are crude because of the lack of historical data for hydrogen as a transportation fuel and the uncertainty as to how the retail market will ultimately develop. Staff reviewed over 13 studies and hydrogen industry sources to develop a range of possible future hydrogen prices for this analysis. After careful review, six of the studies were used to determine the price range used in this analysis.

The expected costs to produce, compress, transport, store and dispense hydrogen were all included. Some of the six studies combined cost components, making it difficult to compare the estimates. The original estimates were modified where possible to reflect California Energy Commission forecasted values.

Costs to produce hydrogen at remote sites outside of California were not modified. In-state hydrogen production costs were modified to reflect the Energy Commission's natural gas price forecast, as natural gas is the feedstock used to produce the hydrogen. Also, in two cases the original production facility capital cost estimates were updated to be consistent with other assumptions used in this work. Specifically, staff assumed a lower bound capital cost at 27 cents per gallon of gasoline equivalent (gge) from the H2Gen study and an upper bound of 58 cents per gge from the Argonne National Lab study. For consistency with other options, costs were annualized using a 12 percent interest rate and a 20-year life.

Operation and maintenance costs for hydrogen production were based upon existing Califonria Public Utilities Commission adopted tariffs for natural gas, as a surrogate for hydrogen compression costs. These tariffs were adjusted to account for hydrogen's lower energy content and higher work of compression required for the 6,500 psi hydrogen gas discharge pressure needed. Maintenance costs were increased by 13 percent for the higher pressure and 50 percent for the lower energy content. Compressor capital costs were estimated to range from $125,000 to $140,000. These values were also annualized using a 12 percent interest rate and 20-year life.

Retail markup was estimated to range from 15 to 22.5 cents gge. Recent gasoline retail markups range from 5 to 12 cents per gallon. The hydrogen markup is scaled up to reflect the need to cover fixed costs, and the smaller volume of sales of hydrogen. Road excise taxes were excluded, as there is currently scant use of hydrogen for transportation, and there is no excise tax on hydrogen. If a significant transportation market for hydrogen develops, this will likely change, leading to higher costs to consumers.

The lower and upper values of each cost component in each of the six studies was summed to obtain lower and upper bound prices for each study. Then the six lower values were averaged and equalled $2.31 per gge. Similarly, the six upper values averaged $4.24 per gge.

Methanol Prices. According to Jim Crocco of Crocco and Associates, the global methanol industry is undergoing several significant changes, which should keep methanol prices low or falling for this decade, and perhaps beyond. These factors include:

- Lower offshore feedstock pricing.
- Much larger and more economical plants built in remote areas.
- Better maintenance and longer lasting catalysts that provide more “on line” time, contributing to lower overall production costs.
- Larger dedicated methanol tankers with lower delivery costs.

Over the long-term, it is feasible that increased demand for methanol, including from methanol FCVs, could cause price increases if supply lags demand for an extended period. Because methanol is a world commodity and an important chemical feedstock, its price will continue to be volatile at times because of such factors as major plant shutdowns, economic or military surprise, etc.

Staff developed a range of expected future methanol prices from a report titled ***Bringing Fuel Cell Vehicles to Market: Scenarios and Challenges with Fuel Alternatives***.[7] The report indicates a pre-tax retail price of $0.787 per gallon of methanol, plus a federal excise tax of $0.093 per gallon, a state excise tax of $0.09 per gallon and a state sales tax equivalent to another $0.06 per gallon for a total of $1.03 per gallon of methanol. Staff used a methanol price range of $0.93 to $1.14 to account for fuel price uncertainty. This was developed by assuming that the wholesale methanol price could be 15 percent lower or 40 percent higher than its midpoint value, then adding taxes.

Gasoline Prices. For this exercise, staff assumed that California gasoline after 2010 will be compatible with both ICE vehicles as well as gasoline FCVs. This will likely require refiners to produce an ultra-low sulfur fuel with minimal or no detergents and other additives commonly used in today’s gasoline. No price differential exists for this scenario (assumes base case of $1.64/gallon).

Should future pump gasoline be found unsatisfactory for FCV reformers, a segregated clean hydrocarbon fuel will need to be provided for FCVs to find commercial success. This could be a special blend of gasoline or other petroleum-based fuel, such as naphtha. Regardless of the feedstock, segregating this fuel from pump gasoline will add cost to the fuel. It is likely to add several cents to each gallon of fuel.[8]

Other Operating Costs. Other costs of operating a FCV, such as insurance, maintenance and repairs, are not well known. Given the relative lack of experience of a pre-commercial vehicle technology, it is unclear whether these costs would be either higher or lower than conventional gasoline ICE vehicles. For this report staff assumed that the costs are similar to gasoline ICE vehicles.

The spreadsheet analysis assumes FCV cost and performance targets of the DOE R&D programs are aproached or met. Vehicle owners will probably still have to pay more to purchase a FCV than a comparable gasoline ICE, even if R&D targets are met. However, expected fuel savings and possible higher value features of FCVs (e.g., quieter operation and increased power availability) may justify a higher vehicle purchase price.

Results

The results of a lifecycle cost analysis are shown in Tables 2A-2 through 2A-4 for direct hydrogen FCVs, Tables 2A-5 through 2A-7 for methanol FCVs and Tables 2A-8 through 2A-10 for gasoline FCVs. The top left of each table shows consumer benefits, changes in government revenue and net benefits. Costs are represented with parentheses and results are expressed in present value 2001 dollars summed over the time periods indicated. Below that are the savings in each year indicated, in millions of 2001 dollars. The middle box shows the amount and percent of gasoline displaced over the same time periods. The bottom left portion of the table shows consumer benefits, changes in government revenue and net benefits in the year indicated divided by the gallons saved in the same year to scale the costs by the amount of fuel saved. Major input assumptions are shown in the right portion of each table.

A potential additional use of fuel cell vehicles is to use them as distributed resources to provide electric power to the grid. With funding from the Air Resources Board and Los Angeles Department of Water and Power, analysts at the University of Delaware evaluated the cost effectiveness of using fuel cell vehicles in this manner.[9] However, staff did not include any potential revenues from the so called "vehicle-to-grid" use of fuel cell vehicles. The amount of revenue that could be derived from this potential application is not known, especially considering that there are several forms of potential distributed generation. Some of these may be more economically viable than fuel cell vehicles but they were not considered in the University of Delaware study. See Option 2C (Grid-Connected Hybrid Electric Vehicles) for a more complete discussion of this topic.

Direct Hydrogen FCVs. Table 2A-3 displays the summary results for direct hydrogen FCVs at our midpoint fuel prices. Even though they are assumed to achieve a fuel economy of 2.5 times that of a comparable gasoline vehicle, on a life cycle cost basis direct hydrogen FCVs may cost more to operate. Direct hydrogen FCVs are expected to cost from $1,800 to $5,000 more to purchase than a similar gasoline internal combustion engine (ICE) vehicle.[10]

Between 2012 (first year of introduction) and 2020, the results indicate that owners would spend an extra $14 to $470 million to operate these vehicles rather than comparable gasoline vehicles.

Correspondingly, government would lose $246 million in revenue, for net costs of $260 to $716 million. These values grow in later years, as shown in the table.

When the costs are evaluated for individual years, similar results are seen. In 2020, consumers would lose $0 to $300 million while government would lose 172 million. Net losses would total $171 to $471 million. Again, values would grow in later years.

On the other hand, direct hydrogen FCVs would displace 2.6 percent of the gasoline that would otherwise be used by light-duty vehicles in 2020 and 8.8 percent in 2030. Displacing each gallon of gasoline using direct hydrogen FCVs would cost $00.33 to $0.92 in 2020 and $0.28 to $0.77 in 2030.

Methanol FCVs. Table 2A-6 displays the summary results for methanol FCVs at our midpoint fuel prices. Even though they are assumed to achieve a fuel economy of 1.7 times that of a comparable gasoline internal combustion engine (ICE) vehicle, on a life cycle cost basis methanol FCVs are expected to cost more to operate. Methanol FCVs are expected to cost $2,300 to $6,000 more to purchase than a comparable ICE vehicle.

Between 2012 (first year of introduction) and 2020, the spreadsheet results indicate that owners would spend an extra $371 to $898 million to operate these vehicles rather than comparable gasoline vehicles. Correspondingly, government would lose $91 million in revenue, for net costs of $461 to $988 million. These values grow in later years as shown in the table.

When the costs are evaluated for individual years, similar results are seen. In 2020, consumers would lose $246 to $893 million while government would lose $63 million. Net losses would total $309 to $838 million. Again, these values grow in later years.

On the other hand, methanol FCVs would displace 2.6 percent of the gasoline that would otherwise used by light-duty vehicles in 2020 and 8.8 percent in 2030. Displacing each gallon of gasoline using methanol FCVs would cost $0.60 to $1.28 in 2020 and $0.53 to $1.10 in 2030.

Gasoline FCVs. Table 2A-9 displays the summary results for gasoline FCVs at our midpoint fuel prices. Even though they are assumed to achieve a fuel economy of 1.5 times that of a comparable gasoline vehicle, on a life cycle cost basis direct hydrogen FCVs may cost more to operate. Gasoline FCVs are expected to cost from $3,400 to $6,500 more to purchase than a comparable ICE vehicle.

Between 2012 (first year of introduction) and 2020, the results indicate that owners would spend an extra $82 to $524 million to operate these vehicles rather than comparable gasoline vehicles. Correspondingly, government would lose $82 million in revenue, for net costs of $164 to $606 million. These values grow in later years as shown in the table.

When the costs are evaluated for individual years, similar results are seen. In 2020, consumers would lose $38 to $329 million while government would lose $57 million. Net losses would total $95 to $386 million. These values turn into consumer savings in later years at the midpoint price range, as shown in the table. However, the consumer savings are not sufficient to overcome the government revenue losses.

On the other hand, gasoline FCVs would displace 0.9 percent of the gasoline forecasted to be used by light-duty vehicles in 2020 and 2.9 percent in 2030. These percentages are lower than either the direct hydrogen or methanol FCVs because gasoline FCVs use gasoline and consequently displace significantly less gasoline. Thus, there are fewer displaced gallons to divide into the costs, and gasoline FCVs cost more for each gallon displaced. Displacing each gallon of gasoline using gasoline FCVs would cost $0.56 to $2.25 in 2020 and $0.26 to $1.68 in 2030.

Key Drivers and Uncertainties

Highlighted below are many of the major uncertainties with FCVs and the key drivers that will ultimately determine the market success of this emerging technology.

- Costs of fuel cell system (success in meeting capital cost R&D targets) and available incentives.
- Feasibility of meeting efficiency goals established by the federal government and industry.
- Technical advances for fuel cell stack, balance of plant and hydrogen storage.
- The willingness of energy industry or government to invest and initially share the cost of fueling infrastructure development, particularly important for hydrogen.
- System efficiency of fuel cell vehicles (success in meeting efficiency R&D targets).
- Choice of fuel or fuels for FCVs. Several candidates are under consideration and this issue should be resolved as fuel cell stack technology advances. There is a general consensus that hydrogen is the preferred fuel in the long term, pending resolution of supply and storage issues.
- Costs of fuel for FCVs, especially hydrogen.

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[1] Arthur D. Little, Guidance for Transportation Technologies: Fuel Choice for Fuel Cell Vehicles, December 2001 (p. 81).

[2] U.S. Department of Energy, FY 2002 Congressional Budget Request, Energy Efficiency and Renewable Energy, Energy Conservation.

[3] www.energy.gov/HQPress/releases02/janpr/pr02001.htm.

[4] U.S. Department of Energy, 2001 Annual Progress Report, Fuel Cells for Transportation, Energy Efficiency and Renewable Energy, Office of Transportation Technologies.

[5] http://www.energy.gov/HQPress/releases02/janpr/pr02001.htm.

[6] Arthur D. Little, Projected Automotive Fuel Cell Use in California, October 2001.

[7] BKI, Bringing Fuel Cell Vehicles to Market: Scenarios and Challenges with Fuel Alternatives, October 2001.

[8] Schremp, Gordon, personal communication, California Energy Commission, 2001.

[9] Kempton, Willett; Tomic and Jasna, University of Delaware; Letendre, Steven, Green Mountain College; Brooks, Alec, AC Propulsion, Inc.; and Lipman, Timothy University of California, Berkley and Davis (2001).

[10] Contadini, J. Fernando, Social Cost Comparison Among Fuel Cell Vehicle Alternatives; (www.methanol.org/fuelcell/special/contadini_pg7.html).

Table 2A-2

Summary of Analysis Results
Option 2A: Fuel Cells
Case: Hydrogen FCVs; Fuel Price: $1.47

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2020	($311)	$145	($246)	($246)	($556)	($101)
2002 to 2030	($1,468)	$1,149	($1,604)	($1,604)	($3,072)	($455)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$0	$0	$0	$0	$0	$0
2020	($189)	$112	($172)	($172)	($360)	($60)
2030	($431)	$530	($655)	($655)	($1,086)	($125)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	0	0	2010	0	0	0.0%	0.0%
2002 to 2020	1,628	1,628	2020	514	514	2.6%	2.6%
2002 to 2030	14,896	14,896	2030	1,961	1,961	8.8%	8.8%

(Columns Year through High % are "Fuel Displaced in Year Indicated".)

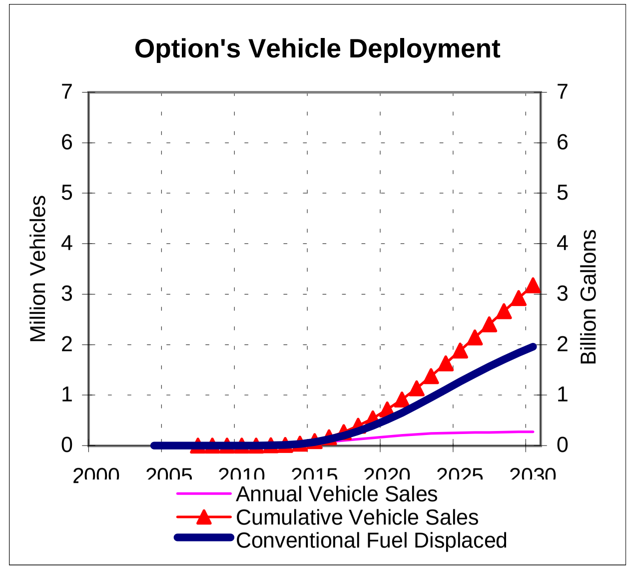
2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2020	($0.37)	$0.22	($0.33)	($0.33)	($0.70)	($0.12)
2030	($0.22)	$0.27	($0.33)	($0.33)	($0.55)	($0.06)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.
[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
Low Fuel Price Estimate ($/gallon)	$1.47
For This Option:	
Vehicle Fuel Economy (mi/gallon)	53.0
High Incremental Cost ($ per vehicle)	$5,000
Low Incremental Cost ($ per vehicle)	$1,800
High Fuel Price ($/GGE)	$2.31
Low Fuel Price ($/GGE)	$2.31
Vehicle Life (years)	15
Discount Rate (%)	5%



GGE = Gallons Gasoline Equivlanet

Table 2A-3

Summary of Analysis Results
Option 2A: Fuel Cells
Case: Hydrogen FCVs; Fuel Price: $1.64

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$0	$0	$0	$0	$0	$0
2002 to 2020	($470)	($14)	($246)	($246)	($716)	($260)
2002 to 2030	($2,509)	$108	($1,604)	($1,604)	($4,113)	($1,496)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$0	$0	$0	$0	$0	$0
2020	($300)	$0	($172)	($172)	($471)	($171)
2030	($857)	$105	($655)	($655)	($1,512)	($550)

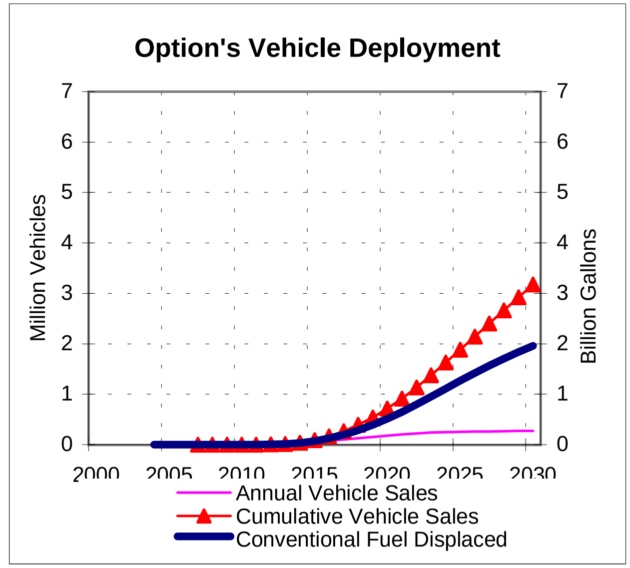
MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.64
Low Fuel Price Estimate ($/gallon)	$1.64
For This Option:	
Vehicle Fuel Economy (mi/gallon)	53.0
High Incremental Cost ($ per vehicle)	$5,000
Low Incremental Cost ($ per vehicle)	$1,800
High Fuel Price ($/GGE)	$3.28
Low Fuel Price ($/GGE)	$3.28
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	0	0	2010	0	0	0.0%	0.0%
2002 to 2020	1,628	1,628	2020	514	514	2.6%	2.6%
2002 to 2030	14,896	14,896	2030	1,961	1,961	8.8%	8.8%

(Fuel Displaced in Year Indicated: columns Year through High %)



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2020	($0.58)	$0.00	($0.33)	($0.33)	($0.92)	($0.33)
2030	($0.44)	$0.05	($0.33)	($0.33)	($0.77)	($0.28)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

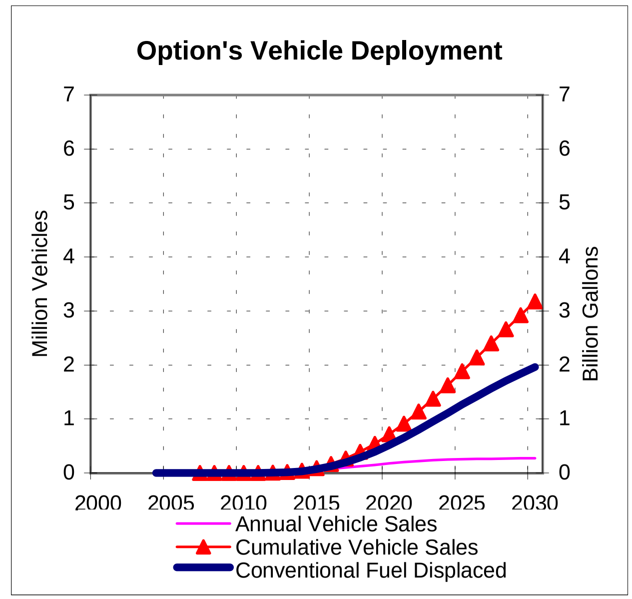
GGE = Gallons Gasoline Equivlanet

	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$0	$0	$0	$0	$0	$0
2002 to 2020	($630)	($174)	($246)	($246)	($876)	($420)
2002 to 2030	($3,550)	($933)	($1,604)	($1,604)	($5,154)	($2,537)

Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.81
Low Fuel Price Estimate ($/gallon)	$1.81
Vehicle Fuel Economy (mi/gallon)	53.0
High Incremental Cost ($ per vehicle)	$5,000
Low Incremental Cost ($ per vehicle)	$1,800
High Fuel Price ($/GGE)	$4.24
Low Fuel Price ($/GGE)	$4.24
Vehicle Life (years)	15
Discount Rate (%)	5%

2010	$0	$0	$0	$0	$0	$0
2020	($411)	($111)	($172)	($172)	($583)	($283)
2030	($1,282)	($321)	($655)	($655)	($1,937)	($976)

	Low	High	Year	Low	High	Low %	High %
2002 to 2010	0	0	2010	0	0	0.0%	0.0%
2002 to 2020	1,628	1,628	2020	514	514	2.6%	2.6%
2002 to 2030	14,896	14,896	2030	1,961	1,961	8.8%	8.8%



GGE = Gallons Gasoline Equivlanet

2001 Dollars Per Gallon of Conventional Fuel Displaced

	[1]	[2]	Low	High	[1]	[2]
2010	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2020	($0.80)	($0.22)	($0.33)	($0.33)	($1.13)	($0.55)
2030	($0.65)	($0.16)	($0.33)	($0.33)	($0.99)	($0.50)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2A-5

Summary of Analysis Results
Option 2A: Fuel Cells
Case: Methanol FCVs; Fuel Price: $1.47

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$0	$0	$0	$0	$0	$0
2002 to 2020	($562)	($34)	($91)	($91)	($652)	($125)
2002 to 2030	($2,993)	$33	($591)	($591)	($3,584)	($559)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$0	$0	$0	$0	$0	$0
2020	($358)	($11)	($63)	($63)	($369)	($74)
2030	($1,021)	$91	($241)	($241)	($930)	($151)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	0.0	0.0	2010	0	0	0.0%	0.0%
2002 to 2020	1,628	1,628	2020	514	514	2.6%	2.6%
2002 to 2030	14,896	14,896	2030	1,961	1,961	8.8%	8.8%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2020	($0.70)	($0.02)	($0.12)	($0.12)	($0.82)	($0.14)
2030	($0.52)	$0.05	($0.12)	($0.12)	($0.64)	($0.08)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

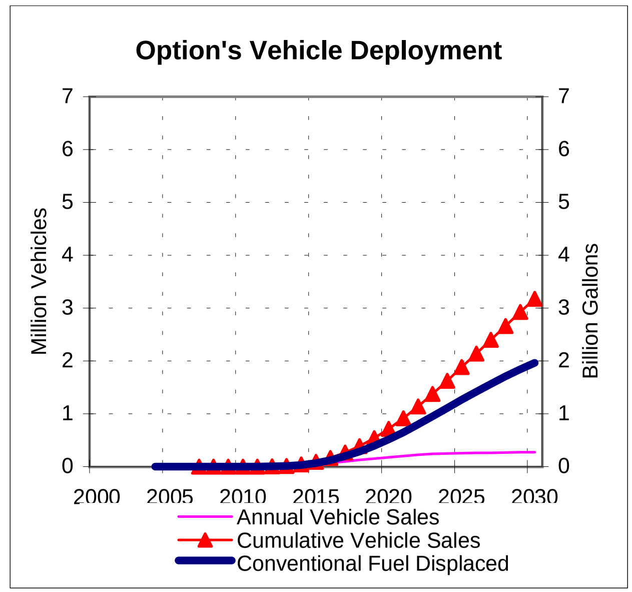
MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:

Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.47
Low Fuel Price Estimate ($/gallon)	$1.47

For This Option:

Vehicle Fuel Economy (mi/gallon)	18.4
High Incremental Cost ($ per vehicle)	$6,000
Low Incremental Cost ($ per vehicle)	$2,300
High Fuel Price ($/Gallon)	$0.93
Low Fuel Price ($/Gallon)	$0.93
Vehicle Life (years)	15
Discount Rate (%)	5%



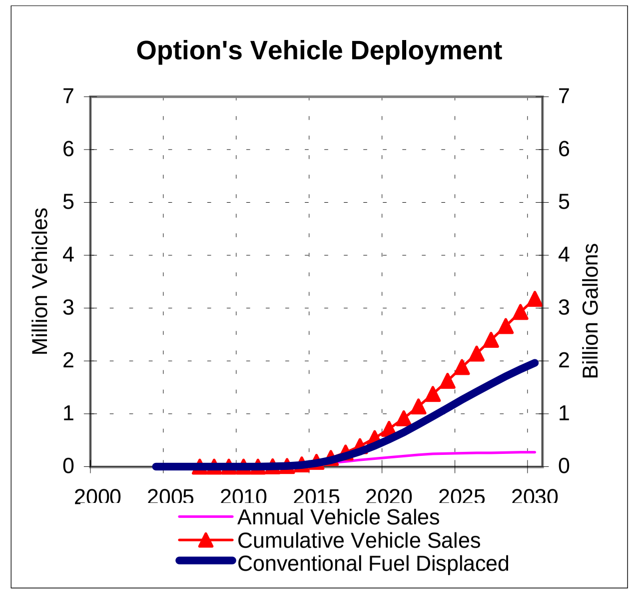
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$0	$0	$0	$0	$0	$0
2002 to 2020	($525)	$2	($91)	($91)	($616)	($89)
2002 to 2030	($2,757)	$268	($591)	($591)	($3,349)	($323)

Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.64
Low Fuel Price Estimate ($/gallon)	$1.64

2010	$0	$0	$0	$0	$0	$0
2020	($333)	$14	($63)	($63)	($319)	($49)
2030	($925)	$187	($241)	($241)	($738)	($55)

Vehicle Fuel Economy (mi/gallon)	18.4
High Incremental Cost ($ per vehicle)	$6,000
Low Incremental Cost ($ per vehicle)	$2,300
High Fuel Price ($/Gallon)	$1.035
Low Fuel Price ($/Gallon)	$1.035
Vehicle Life (years)	15
Discount Rate (%)	5%

	Low	High	Year	Low	High	Low %	High %
2002 to 2010	0.0	0.0	2010	0	0	0.0%	0.0%
2002 to 2020	1,628	1,628	2020	514	514	2.6%	2.6%
2002 to 2030	14,896	14,896	2030	1,961	1,961	8.8%	8.8%



	[1]	[2]	Low	High	[1]	[2]
2010	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2020	($0.65)	$0.03	($0.12)	($0.12)	($0.77)	($0.10)
2030	($0.47)	$0.10	($0.12)	($0.12)	($0.59)	($0.03)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2A-7

Summary of Analysis Results
Option 2A: Fuel Cells
Case: Methanol; Fuel Price: $1.81

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$0	$0	$0	$0	$0	$0
2002 to 2020	($489)	$38	($91)	($91)	($580)	($53)
2002 to 2030	($2,522)	$504	($591)	($591)	($3,113)	($88)

Single Year Savings in Millions of 2001 Dollars

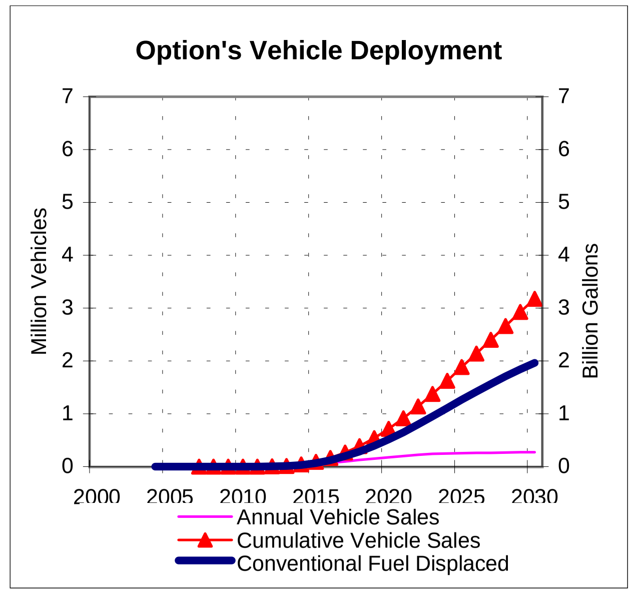
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$0	$0	$0	$0	$0	$0
2020	($308)	$39	($63)	($63)	($268)	($24)
2030	($828)	$283	($241)	($241)	($546)	$41

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.81
Low Fuel Price Estimate ($/gallon)	$1.81
For This Option:	
Vehicle Fuel Economy (mi/gallon)	18.4
High Incremental Cost ($ per vehicle)	$6,000
Low Incremental Cost ($ per vehicle)	$2,300
High Fuel Price ($/Gallon)	$1.14
Low Fuel Price ($/Gallon)	$1.14
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated Low	High	Low %	High %
2002 to 2010	0.0	0.0	2010	0	0	0.0%	0.0%
2002 to 2020	1,628	1,628	2020	514	514	2.6%	2.6%
2002 to 2030	14,896	14,896	2030	1,961	1,961	8.8%	8.8%



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2020	($0.60)	$0.08	($0.12)	($0.12)	($0.72)	($0.05)
2030	($0.42)	$0.14	($0.12)	($0.12)	($0.55)	$0.02

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

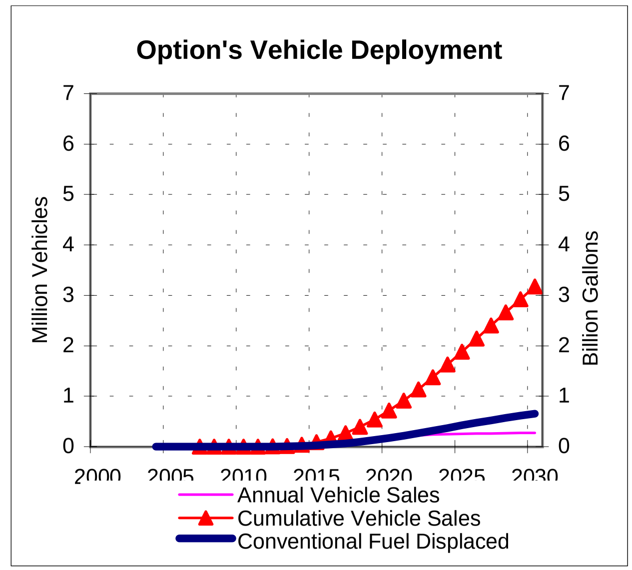
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$0	$0	$0	$0	$0	$0
2002 to 2020	($565)	($124)	($82)	($82)	($647)	($206)
2002 to 2030	($2,962)	($427)	($535)	($535)	($3,497)	($962)

Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.47
Low Fuel Price Estimate ($/gallon)	$1.47

2010	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2020	($358)	($67)	($57)	($57)	($415.0)	($124.3)
2030	($991)	($60)	($218)	($218)	($1,209.7)	($278.7)

Vehicle Fuel Economy (mi/gallon)	31.8
High Incremental Cost ($ per vehicle)	$6,500
Low Incremental Cost ($ per vehicle)	$3,400
High Fuel Price ($/gallon)	$1.47
Low Fuel Price ($/gallon)	$1.47
Vehicle Life (years)	15
Discount Rate (%)	5%

	Low	High	Year	Low	High	Low %	High %
2002 to 2010	0	0	2010	0.0	0.0	0.0%	0.0%
2002 to 2020	543	543	2020	171	171	0.9%	0.9%
2002 to 2030	4,965	4,965	2030	654	654	2.9%	2.9%



	[1]	[2]	Low	High	[1]	[2]
2010	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2020	($2.09)	($0.39)	($0.33)	($0.33)	($2.42)	($0.73)
2030	($1.52)	($0.09)	($0.33)	($0.33)	($1.85)	($0.43)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

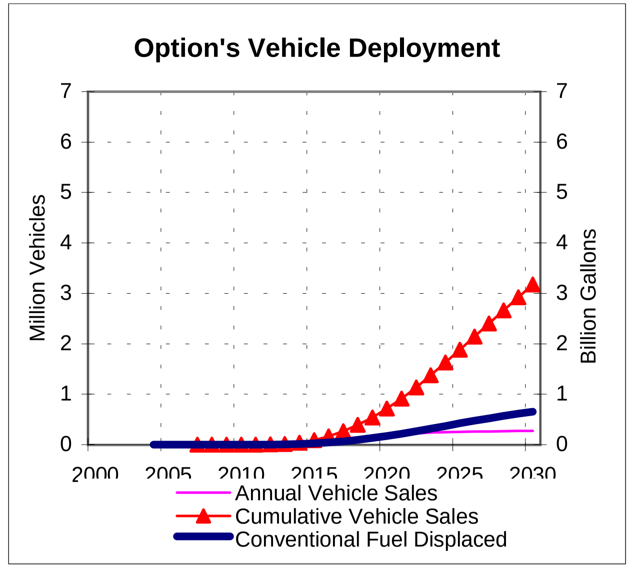
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$0	$0	$0	$0	$0	$0
2002 to 2020	($524)	($82)	($82)	($82)	($606)	($164)
2002 to 2030	($2,690)	($155)	($535)	($535)	($3,225)	($690)

Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.64
Low Fuel Price Estimate ($/gallon)	$1.64

Vehicle Fuel Economy (mi/gallon)	31.8
High Incremental Cost ($ per vehicle)	$6,500
Low Incremental Cost ($ per vehicle)	$3,400
High Fuel Price ($/gallon)	$1.64
Low Fuel Price ($/gallon)	$1.64
Vehicle Life (years)	15
Discount Rate (%)	5%

2010	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2020	($329)	($38)	($57)	($57)	($386)	($95)
2030	($880)	$51	($218)	($218)	($1,099)	($168)

	Low	High	Year	Low	High	Low %	High %
2002 to 2010	0	0	2010	0.0	0.0	0.0%	0.0%
2002 to 2020	543	543	2020	171	171	0.9%	0.9%
2002 to 2030	4,965	4,965	2030	654	654	2.9%	2.9%



	[1]	[2]	Low	High	[1]	[2]
2010	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2020	($1.92)	($0.22)	($0.33)	($0.33)	($2.25)	($0.56)
2030	($1.35)	$0.08	($0.33)	($0.33)	($1.68)	($0.26)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2A-10

Summary of Analysis Results
Option 2A: Fuel Cells
Case: Gasoline; Fuel Price: $1.81

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$0	$0	$0	$0	$0	$0
2002 to 2020	($482)	($40)	($82)	($82)	($564)	($122)
2002 to 2030	($2,418)	$117	($535)	($535)	($2,953)	($418)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2020	($300)	($9)	($57)	($57)	($356.8)	($66.1)
2030	($769)	$162	($218)	($218)	($987.5)	($56.4)

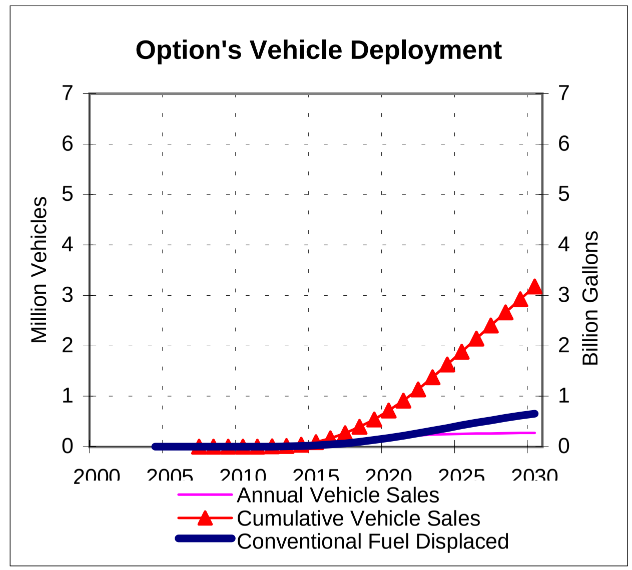
MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.81
Low Fuel Price Estimate ($/gallon)	$1.81
For This Option:	
Vehicle Fuel Economy (mi/gallon)	31.8
High Incremental Cost ($ per vehicle)	$6,500
Low Incremental Cost ($ per vehicle)	$3,400
High Fuel Price ($/gallon)	$1.81
Low Fuel Price ($/gallon)	$1.81
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	0	0	2010	0.0	0.0	0.0%	0.0%
2002 to 2020	543	543	2020	171	171	0.9%	0.9%
2002 to 2030	4,965	4,965	2030	654	654	2.9%	2.9%

(Columns Year through High % are "Fuel Displaced in Year Indicated".)



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2020	($1.75)	($0.05)	($0.33)	($0.33)	($2.08)	($0.39)
2030	($1.18)	$0.25	($0.33)	($0.33)	($1.51)	($0.09)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.
[2] This result represents the opposite of [1].

Staff Paper on Option 2B
Electric Battery Technologies

Description

This option would provide additional funding to reduce the cost of battery-powered electric drive vehicles, and provide additional incentives equal to the incremental cost of a battery electric vehicles to reach market penetration levels which exceed the Air Resources Board's Zero Emission Vehicle (ZEV) mandate.

Background

In 1990, the California Air Resources Board (ARB) adopted low-emission vehicle standards that included a requirement that automobile manufacturers offer a minimum percentage of zero-emission vehicles for sale. Although the actual minimum percentage has been reduced over the past 12 years, there is still a requirement that manufacturers produce and offer for sale, a limited number of zero-emission vehicles beginning in model year 2003. ARB, however, is amending these requirements as a result of successful litigation by automobile manufacturers. The commercialization status of zero-emission vehicle technology limits automaker options to battery powered electric vehicles.

The development of more cost-effective battery electric drive technologies can potentially improve the competitiveness of battery-electric vehicles, fuel cell vehicles, and gasoline- electric hybrid vehicles. With additional research and development (R&D), technology advancements could increase the range and utility of these vehicles resulting in an increased number of vehicles that could be introduced in California beyond the minimum number required by the ZEV regulation.

These technology improvements may only have a marginal impact on gasoline consumption, however, since battery electric vehicles are already included in the base case forecast at levels required by California's Low-Emission Vehicle Standards.

Neighborhood electric vehicles are excluded from this option. Preliminary results from demonstrations with these vehicles have revealed that they consume relatively few gallons of gasoline per year, and therefore are not be expected to displace much petroleum. However, staff has included city electric vehicles (also called urban electric vehicles) in this evaluation.

Status

In efforts by automobile manufacturers to meet the ARB's ZEV program requirements, a limited number of electric drive vehicles have been offered for lease or sale. The battery electric vehicles being sold today have an incremental battery cost premium of $30,000 relative to similar gasoline powered internal combustion engine vehicles. City electric vehicles available today have an incremental cost of $20,000. However, the range of these vehicle classes and the durability of their batteries have not approached the performance of similar gasoline internal combustion vehicles.

In their 1995 report, The Advanced Battery Panel estimated that in order to reach their projected cost targets, investments in R&D and in a battery plant capable of producing batteries in volumes needed to lower unit cost would be between $180 million and $400 million over 9 years.[1] Current research and development aimed at reducing battery costs is low and declining compared to recent historical levels.[2] Federal electric vehicle R&D during that time focused on attempts to reduce battery costs. Presently, the scope of the panel's R&D funding is being reduced to concentrate instead on fuel cell vehicles.

Assumptions

Staff assumed that the ZEV mandate is met, and the base case demand level incorporates the effect of the ZEV mandate in reducing gasoline demand. To increase market penetration, lower cost batteries would be needed and there needs to be additional vehicle purchase incentives to offset the additional capital cost.

This analysis assumes that further research and development will eventually reduce the cost of batteries into the range projected by the Air Resources Board's Battery Technology Advisory Panel. This independent panel stated that nickel-metal hydride batteries show the greatest potential for reaching technical maturity and cost targets. The panel projected the mature technology cost to range from $225 to $250 per kWh in large production quantities of 100,000 battery packs per year.[3] This leads to an incremental price of $8,000 to $10,000 per vehicle including an additional cost of $600 to $1,200 per vehicle for electric and thermal management systems and $1,000 for home recharging infrastructure.

Recent information presented to Air Resources Board staff by one battery manufacturer estimated that Lithium-Metal-Polymer battery costs could reach $200/kWh in high production levels.[4] This level would result in an incremental vehicle cost of approximately $7,600. Furthermore, the U.S. Advanced Battery Consortium has a goal of $150 per kWh and 300 watts per kilogram with a 10-year life using lithium-based batteries.[5] The major U.S. automobile manufacturers and DOE have jointly spent nearly $300 million since 1991 to develop such advanced batteries.

For city vehicles, staff assumed that the cost of batteries for city EV would be approximately one-third the cost of full size battery modules with an equivalent fuel economy of 45 miles per gallon compared to the average vehicle fuel economy.[6]

One strategy for improving the cost-effectiveness of electric drive vehicles, including electric battery vehicles, is to use them for Ancillary Services while connected to the electric grid. See Option 2C (Grid-Connected Hybrid Electric Vehicles) for a discussion on this additional potential source of revenue. The effect of this additional revenue, if realized, would improve the cost-effectiveness of electric drive vehicles.

Battery-electric vehicle target costs and performance levels have been difficult to achieve, although some gains have occurred over the past 10 years. The capital cost, range and operating cost of a full-function battery-electric vehicle (EV) are considerably less attractive than a gasoline powered internal combustion engine vehicle. Nevertheless, there are potentially significant environmental benefits and strong advocates for their use. If a mature market develops (beyond the mandated level of market penetration), it will occur because R&D is expanded and materials costs are reduced. This process will take time. If the cost and performance targets used in the mature market condition are met, a small number of full-function EVs could be operating in California by 2010, growing thereafter.

For consistency with other Group 2 (Fuel Substitution) options, staff assumed that battery-electric vehicle deployment begins in 2008. For battery-electric vehicles to achieve these deployment levels, major technical and economic breakthroughs need to occur prior to 2008. These would include reducing the cost of the batteries and extending battery life.

By assuming that R&D cost and performance targets discussed above are met and adding a cost of $1,000 per vehicle for home recharging equipment and installation, staff estimated a battery EV's lifecycle cost to vehicle owners and government. Battery replacement cost is assumed to be zero (assumes batteries last the 15 year life of the vehicle). No additional consumer cost benefits or disbenefits are included (i.e., convenience of home refueling, availability of public refueling/recharging, or loss of operating range) as these are difficult to quantify.

Staff assumed a range of 6.2 to 13.5 cents per kWh for the cost of recharging the battery. This is the range of residential retail prices estimated by the Energy Commission for Pacific Gas and Electric, Southern California Edison, San Diego Gas and Electric, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District territories out through 2012.[7] The lower number includes a 40 percent discount for off-peak charging.

Results

Tables 2B-1 through 2B-3 show results for the full size battery EVs and Tables 2B-4 through 2B-6 show results for City EVs. Negative values in the tables are costs either to the consumer or to the government and are shown with parentheses. The remainder represents savings to consumers or government.

Full Size EVs. Table 2B-2 displays the results for full size battery EVs at the midpoint fuel price. The capital cost of a full size battery-electric vehicle is expected to range from $7,600 to $10,000 more than the cost of a comparable conventional gasoline vehicle. Between 2008 and 2010, with a total of 15,000 battery-electric vehicles operating, electric drive vehicles are expected to cost owners $41 to $60 million more to operate than gasoline vehicles, on a net present value basis and expressed in year 2001 dollars. Correspondingly, government would lose $11 million in revenue, for net costs of $51 to $708 million. These costs grow in later years, as shown in the table.

When the costs are evaluated for individual years, similar results are seen. In 2010, consumers would lose $37 to $55 million while government would lose $10 million. Net losses would total $48 to $65 million. Again, these values would grow in later years.

On the other hand, battery-electric vehicles would displace 0.2 percent of the gasoline forecasted to be used by light-duty vehicles in 2010, 5.7 percent by 2020 and 10.4 percent by 2030. Displacing each gallon of gasoline using a battery-electric vehicle would cost $1.56 to $2.14 in 2010, $1.06 to $1.47 in 2020 and $0.83 to $1.17 in 2030. These dollars are in year expended, and are not on a net present value basis.

City EVs. Table 2B-5 displays the results for city EVs at the midpoint fuel price. In this analysis, staff assumed battery costs ranging from $2,333 to $3,400 (plus $1,000 for at-home recharging), with a 50 mile range, compared to a conventional vehicle that has a 21.2 mile per gallon fuel economy. Using the Society of Automotive Engineers utility factors to determine the annual number of vehicle miles traveled that a limited range vehicle would displace, staff calculated the net cost per vehicle to range between $3,733 and $4,733 including $1,000 in home recharging infrastructure.

The cost per gallon of gasoline displaced for the city electric vehicle ranges between a loss of $1.19 to $4.42. These values are higher than the losses calculated for the full size electric vehicle ($0.83 to $2.14 per gallon); therefore, city EVs were not included any further in the evaluation of electric battery vehicles.

Key Drivers and Uncertainties

- There is uncertainty that additional research funding can reduce the cost of manufacturing advanced batteries for electric vehicles to the level assumed in this analysis.

- There is uncertainty in consumer interest in purchasing a battery electric vehicle that would still have less utility compared to a gasoline powered vehicle.

- There is uncertainty on the amount of incentives required to influence consumers to acquire an electric vehicle.

- There is uncertainty in manufacturer interest in producing additional battery electric vehicles for sale.

- There is significant uncertainty in the battery replacement cost. This analysis assumes batteries will last the full 10-year life of the vehicle.

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[1] Performance and Availability of Batteries for Electric Vehicles: a Report of the Battery Technical Advisory Panel. 1995. F.R. Kalhammer, A. Kozawa, C.B. Moyer, B.B. Owens.

[2] The U.S. Department of Energy spent $8.7 million for electric drive vehicle R&D in FY 2000, $9.0 million in FY 2001 and requested only $3.5 million for FY 2002.

[3] Advanced Batteries for Electric Vehicles: An Assessment of Performance, Cost, and Availability, 2000. M. Anderman, F.R. Kalhammer, D. MacArther.

[4] Presentation by Avestor to Tom Cackette, February 2002.

[5] U.S. Advanced Battery Consortium Program Overview, March 2001.

[6] Conversation with Chuck Shulock, March 13, 2002 on City EV batteries in a mature market. ARB staff estimated cost to be 1/3 compared to full size EVs or about $3,400.

[7] 2002—2012 Electricity Outlook Report, P700-01-004F, February 2002, Table III-2-4, adjusted to 2002 dollars.

Table 2B-1

Summary of Analysis Results
Option 2B: Electric Battery Technologies

Case: Full Size EVs; Fuel Price: $1.47

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($53)	($34)	($11)	($11)	($63)	($45)
2002 to 2020	($2,495)	($1,419)	($818)	($818)	($3,313)	($2,237)
2002 to 2030	($6,778)	($3,541)	($2,757)	($2,757)	($9,535)	($6,298)

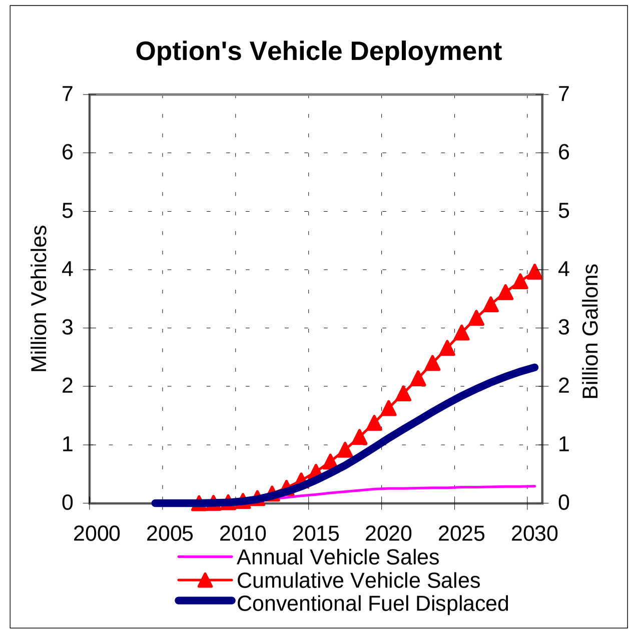
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($48.4)	($30.8)	($10.2)	($10.2)	($58.6)	($41.0)
2020	($1,026.4)	($563.3)	($371.1)	($371.1)	($1,397)	($934)
2030	($1,448.8)	($647.1)	($777.3)	($777.3)	($2,226)	($1,424)

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.47
Low Fuel Price Estimate ($/gallon)	$1.47
For This Option:	
Vehicle Fuel Economy (mi/kWh)	2.0
High Incremental Cost ($ per vehicle)	$10,000
Low Incremental Cost ($ per vehicle)	$7,600
High Fuel Price ($/kWh)	$0.062
Low Fuel Price ($/kWh)	$0.062
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	46	46	2010	31	31	0.2%	0.2%
2002 to 2020	5,139	5,139	2020	1,111	1,111	5.7%	5.7%
2002 to 2030	23,713	23,713	2030	2,327	2,327	10.4%	10.4%



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($1.58)	($1.01)	($0.33)	($0.33)	($1.92)	($1.34)
2020	($0.92)	($0.51)	($0.33)	($0.33)	($1.26)	($0.84)
2030	($0.62)	($0.28)	($0.33)	($0.33)	($0.96)	($0.61)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2B-2

Summary of Analysis Results
Option 2B: Electric Battery Technologies

Case: Full Size EVs; Fuel Price: $1.64

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($60)	($41)	($11)	($11)	($70)	($51)
2002 to 2020	($3,027)	($1,950)	($818)	($818)	($3,845)	($2,768)
2002 to 2030	($8,568)	($5,331)	($2,757)	($2,757)	($11,326)	($8,089)

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($55.0)	($37.4)	($10.2)	($10.2)	($65.2)	($47.6)
2020	($1,267.4)	($804.3)	($371.1)	($371.1)	($1,638)	($1,175)
2030	($1,953.5)	($1,151.9)	($777.3)	($777.3)	($2,731)	($1,929)

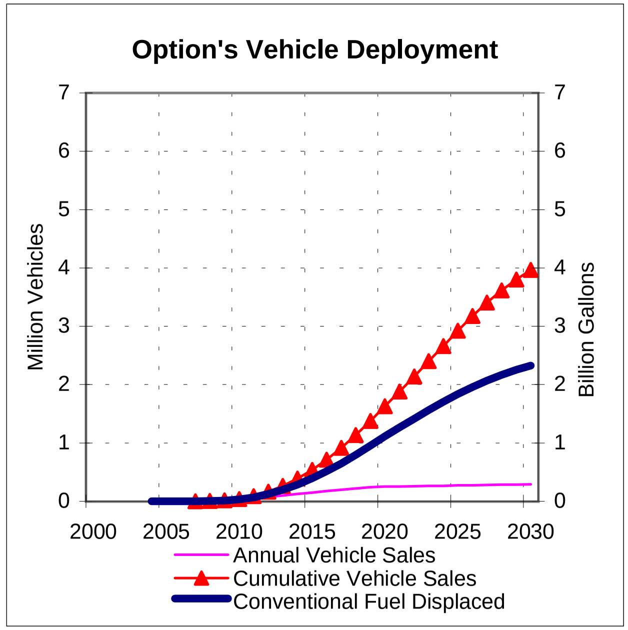
MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.64
Low Fuel Price Estimate ($/gallon)	$1.64
For This Option:	
Vehicle Fuel Economy (mi/kWh)	2.0
High Incremental Cost ($ per vehicle)	$10,000
Low Incremental Cost ($ per vehicle)	$7,600
High Fuel Price ($/kWh)	$0.099
Low Fuel Price ($/kWh)	$0.099
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	46	46	2010	31	31	0.2%	0.2%
2002 to 2020	5,139	5,139	2020	1,111	1,111	5.7%	5.7%
2002 to 2030	23,713	23,713	2030	2,327	2,327	10.4%	10.4%

(Low/High for Year columns: Fuel Displaced in Year Indicated)



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($1.80)	($1.23)	($0.33)	($0.33)	($2.14)	($1.56)
2020	($1.14)	($0.72)	($0.33)	($0.33)	($1.47)	($1.06)
2030	($0.84)	($0.49)	($0.33)	($0.33)	($1.17)	($0.83)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2B-3

Summary of Analysis Results
Option 2B: Electric Battery Technologies

Case: Full Size EVs; Fuel Price: $1.81

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($67)	($48)	($11)	($11)	($77)	($58)
2002 to 2020	($3,558)	($2,481)	($818)	($818)	($4,376)	($3,299)
2002 to 2030	($10,359)	($7,122)	($2,757)	($2,757)	($13,116)	($9,879)

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($61.6)	($44.1)	($10.2)	($10.2)	($71.8)	($54.3)
2020	($1,508.4)	($1,045.3)	($371.1)	($371.1)	($1,879)	($1,416)
2030	($2,458.3)	($1,656.6)	($777.3)	($777.3)	($3,236)	($2,434)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period			Fuel Displaced in Year Indicated				
	Low	High	Year	Low	High	Low %	High %
2002 to 2010	46	46	2010	31	31	0.2%	0.2%
2002 to 2020	5,139	5,139	2020	1,111	1,111	5.7%	5.7%
2002 to 2030	23,713	23,713	2030	2,327	2,327	10.4%	10.4%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($2.02)	($1.44)	($0.33)	($0.33)	($2.35)	($1.78)
2020	($1.36)	($0.94)	($0.33)	($0.33)	($1.69)	($1.27)
2030	($1.06)	($0.71)	($0.33)	($0.33)	($1.39)	($1.05)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.81
Low Fuel Price Estimate ($/gallon)	$1.81
For This Option:	
Vehicle Fuel Economy (mi/kWh)	2.0
High Incremental Cost ($ per vehicle)	$10,000
Low Incremental Cost ($ per vehicle)	$7,600
High Fuel Price ($/kWh)	$0.135
Low Fuel Price ($/kWh)	$0.135
Vehicle Life (years)	15
Discount Rate (%)	5%

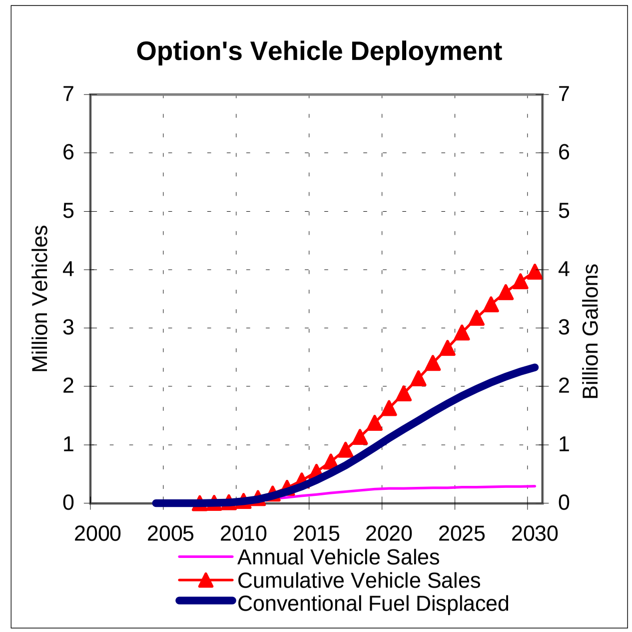


Table 2B-4

Summary of Analysis Results
Option 2B: Electric Battery Technologies

Case: City EVs; Fuel Price: $1.47

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($31)	($23)	($3)	($3)	($34)	($26)
2002 to 2020	($1,641)	($1,192)	($198)	($198)	($1,839)	($1,390)
2002 to 2030	($4,757)	($3,408)	($668)	($668)	($5,426)	($4,077)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($28.6)	($21.3)	($2.5)	($2.5)	($31.1)	($23.8)
2020	($694)	($501)	($90)	($90)	($784)	($591)
2030	($1,122)	($788)	($188)	($188)	($1,311)	($977)

Conventional Fuel Displaced (Million Gallons)

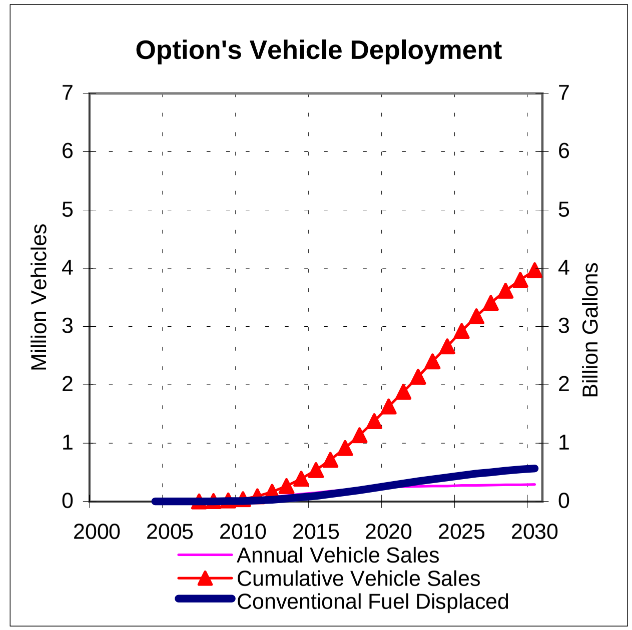
Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
			Fuel Displaced in Year Indicated				
2002 to 2010	11	11	2010	7	7	0.0%	0.0%
2002 to 2020	1,246	1,246	2020	269	269	1.4%	1.4%
2002 to 2030	5,748	5,748	2030	564	564	2.5%	2.5%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($3.87)	($2.88)	($0.33)	($0.33)	($4.20)	($3.21)
2020	($2.58)	($1.86)	($0.33)	($0.33)	($2.91)	($2.20)
2030	($1.99)	($1.40)	($0.33)	($0.33)	($2.32)	($1.73)

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.47
Low Fuel Price Estimate ($/gallon)	$1.47
For This Option:	
Vehicle Fuel Economy (mi/kWh)	2.0
High Incremental Cost ($ per vehicle)	$3,733
Low Incremental Cost ($ per vehicle)	$4,733
High Fuel Price ($/kWh)	$0.062
Low Fuel Price ($/kWh)	$0.062
Vehicle Life (years)	15
Discount Rate (%)	5%



[1] , [2]: Correlated results usually apply. Column [1] represents lower fuel price differences and could include either lower or higher incremental capital costs. Column [2] represents higher fuel price differences and the opposite capital cost from Column [1]. Fuel price differences tend to dominate total cost differences.

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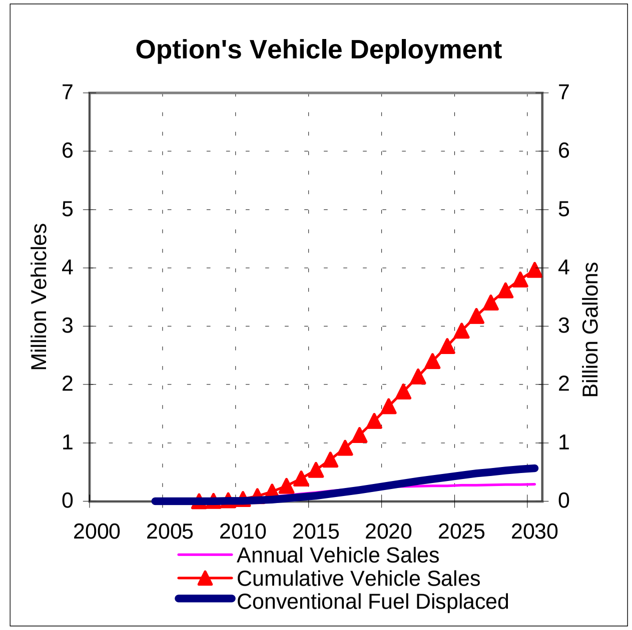
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($33)	($25)	($3)	($3)	($35)	($27)
2002 to 2020	($1,770)	($1,321)	($198)	($198)	($1,968)	($1,519)
2002 to 2030	($5,191)	($3,842)	($668)	($668)	($5,860)	($4,511)

Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.64
Low Fuel Price Estimate ($/gallon)	$1.64
Vehicle Fuel Economy (mi/kWh)	2.0
High Incremental Cost ($ per vehicle)	$3,733
Low Incremental Cost ($ per vehicle)	$4,733
High Fuel Price ($/kWh)	$0.099
Low Fuel Price ($/kWh)	$0.099
Vehicle Life (years)	15
Discount Rate (%)	5%

2010	($30.2)	($22.9)	($2.5)	($2.5)	($32.7)	($25.4)
2020	($753)	($560)	($90)	($90)	($843)	($650)
2030	($1,245)	($911)	($188)	($188)	($1,433)	($1,099)

	Low	High	Year	Low	High	Low %	High %
2002 to 2010	11	11	2010	7	7	0.0%	0.0%
2002 to 2020	1,246	1,246	2020	269	269	1.4%	1.4%
2002 to 2030	5,748	5,748	2030	564	564	2.5%	2.5%



	[1]	[2]	Low	High	[1]	[2]
2010	($4.08)	($3.10)	($0.33)	($0.33)	($4.42)	($3.43)
2020	($2.79)	($2.08)	($0.33)	($0.33)	($3.13)	($2.41)
2030	($2.21)	($1.61)	($0.33)	($0.33)	($2.54)	($1.95)

[1] , [2]: Correlated results usually apply. Column [1] represents lower fuel price differences and could include either lower or higher incremental capital costs. Column [2] represents higher fuel price differences and the opposite capital cost from Column [1]. Fuel price differences tend to dominate total cost differences.

Table 2B-6

Summary of Analysis Results
Option 2B: Electric Battery Technologies

Case: City EVs; Fuel Price: $1.81

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($34)	($26)	($3)	($3)	($37)	($29)
2002 to 2020	($1,898)	($1,450)	($198)	($198)	($2,097)	($1,648)
2002 to 2030	($5,625)	($4,276)	($668)	($668)	($6,294)	($4,945)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($31.8)	($24.5)	($2.5)	($2.5)	($34.3)	($27.0)
2020	($811)	($618)	($90)	($90)	($901)	($708)
2030	($1,367)	($1,033)	($188)	($188)	($1,556)	($1,222)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	11	11	2010	7	7	0.0%	0.0%
2002 to 2020	1,246	1,246	2020	269	269	1.4%	1.4%
2002 to 2030	5,748	5,748	2030	564	564	2.5%	2.5%

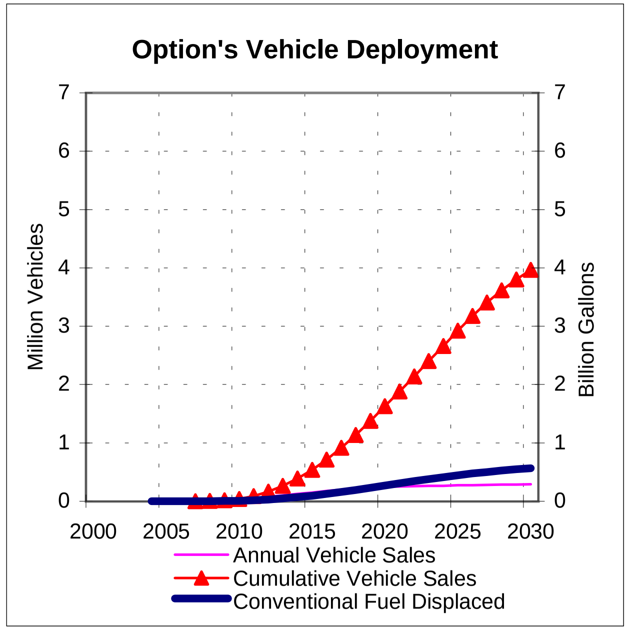
(Low, High, Low % and High % under "Fuel Displaced in Year Indicated")

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($4.30)	($3.31)	($0.33)	($0.33)	($4.64)	($3.65)
2020	($3.01)	($2.29)	($0.33)	($0.33)	($3.35)	($2.63)
2030	($2.42)	($1.83)	($0.33)	($0.33)	($2.76)	($2.17)

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.81
Low Fuel Price Estimate ($/gallon)	$1.81
For This Option:	
Vehicle Fuel Economy (mi/kWh)	2.0
High Incremental Cost ($ per vehicle)	$3,733
Low Incremental Cost ($ per vehicle)	$4,733
High Fuel Price ($/kWh)	$0.135
Low Fuel Price ($/kWh)	$0.135
Vehicle Life (years)	15
Discount Rate (%)	5%



[1] , [2]: Correlated results usually apply. Column [1] represents lower fuel price differences and could include either lower or higher incremental capital costs. Column [2] represents higher fuel price differences and the opposite capital cost from Column [1]. Fuel price differences tend to dominate total cost differences.

Staff Paper on Option 2C
Grid-Connected Hybrid Electric Vehicles

Description

This option examines the use of grid-connected hybrid-electric vehicles (HEVs) to replace gasoline fueled light-duty vehicles.

Background

Grid-connected hybrid-electric vehicles (HEVs) have plug-in capabilities, a larger electric motor and larger batteries than non-grid-connected hybrid-electric vehicles. HEVs also have a gasoline internal combustion engine. This allows them to achieve a portion of their travel on batteries alone and the remainder on gasoline. Given that approximately 63 percent of daily trips are less than 60 miles in length, grid-connected gasoline-electric hybrid vehicles with medium sized battery packs can completely replace one-half of all gasoline powered vehicle trips.[1] Grid-connected HEVs use the same batteries as electric battery vehicles (see Option 2B: Electric Battery Technologies), but have a smaller battery pack and correspondingly lower incremental vehicle cost.

Recently revised "Zero Emission Vehicle" regulations adopted by the California Air Resources Board may encourage automobile manufacturers to re-examine the potential for grid-connected HEVs. If grid-connected hybrid vehicles become available, they could provide an additional reduction in petroleum use compared to conventional gasoline or hybrid vehicles. However, developers still need to address battery and component costs and battery life, especially in this application with frequent shallow charging and discharging cycles.

Status

The U. S. Department of Energy (DOE) is funding research and development of hybrid electric vehicles (not just grid-connected), focusing upon improved battery packs, system component optimization, reduced ancillary loads, advanced power electronics, hybrid/electric propulsion systems, Department of Defense needs, and advanced materials and architectures.[2]

Grid-connected HEVs are also undergoing research at the Electric Power Research Institute (EPRI).[3] EPRI is focusing upon the role of electric drive transportation, including how electric grid operation can be enhanced using distributed technologies, including electric-drive vehicles such as grid-connected HEVs. EPRI is also working with automobile manufacturers and the Department of Defense to examine the potential for electric drive vehicles.

Grid-connected HEVs are also an element in a Vehicle-to-Grid (V-2-G) Power study conducted by the University of Delaware.[4] This study finds grid-connected hybrids to have significant market potential. Several aspects need further work, however, including better estimates of incremental vehicle cost, durability of batteries when used in this mode, and user behavior.[5]

A form of ancillary services called "regulation services" shows particularly strong potential, for being served by grid-connected electric-drive vehicles, since in this mode batteries would be equally charged and discharged, conserving battery energy. Ancillary services have historically been about 5 percent of the California ISO's energy costs, costing about $1.3 billion in the first 10 months of 2001.[6] However, other issues await evaluation, including the market potential for other nontraditional sources of ancillary services.

The largest cost component for grid-connected hybrid electric vehicles is associated with the battery. This is tied directly to the incremental vehicle capital cost, and the degree to which they can displace gasoline vehicle operation. The Air Resources Board's Advanced Battery Panel expects the per vehicle cost of batteries to be $13,000 to $20,000 in production quantities of 100,000 per year, reducing to about $7,000 per vehicle with additional research and development and even greater annual production.[7] See Option 2B (Electric Battery Technologies) for more discussion of battery development research and funding. For the purposes of the analysis reported below, staff used the EPRI battery cost of $270 per kWh.

Assumptions

This estimate of petroleum reduction assumes that these vehicles would be included as a subset of the required sales for Advanced Technology Partial Zero Emission Vehicles (AT PZEVs). Current regulations require approximately 309,000 advanced technology PZEVs to be operating in California by 2010. Staff also assumes that these vehicles would be able to achieve 45 miles per gallon of gasoline during engine operation.

The cost per mile of the 20-mile range HEV (called an HEV-20) and the cost per mile of the HEV-60 appear very similar, although the cost per mile of the HEV-60 is reported by EPRI to be somewhat lower than the HEV-20. Thus, staff analyzed the cost for a grid-connected HEV with a 60-mile range, although others have studied 20- and 40-mile ranges as well as 60-mile range vehicles. While the optimum "zero equivalent" range is still being determined, staff chose to evaluate the cost of the 60-mile range because the cost-effectiveness of the 60-mile vehicle seems slightly better than the 20- or 40- mile vehicles. This difference is based upon their incremental capital costs relative to a gasoline engine, and the corresponding larger volumes of gasoline displacement.

Staff evaluated the lifecycle cost of grid-connected HEVs in terms of vehicle owner costs and government costs, assuming that vehicle related R&D cost and performance targets are met. Staff assumed that 74 percent of their vehicle miles of travel could be in a battery-only mode, at 60 miles per charge and that the fuel economy of these vehicles is 45 miles per gallon while operating on the gasoline engine during longer trips not served by electric-only operation.

Staff also assumed a range of 6.2 to 13.5 cents per kWh for the cost of recharging the vehicle battery pack with a midpoint of 9.9 cents per kWh. This is the range of residential retail prices estimated for the PG&E, SCE, SDG&E, LADWP and SMUD service territories by the California Energy Commission, with the lower value discounted by 40 percent to reflect off-peak charging,[8] as discussed in Option 2B (Electric Battery Technologies). Fuel excise taxes are assumed to be zero for the electric portion of the vehicle's motive force, representing a loss to the government.

This is because staff assumed continuation of the existing practice of no excise taxes on electricity used in transportation.

Using the retail price equivalent comparison developed by the Electric Power Research Institute for a grid connected hybrid electric vehicle that has a 60 mile all electric range, the cost of grid connected HEV-60 in a mature market was estimated to range between $7,000 and $10,200 per vehicle.[9] This is how much more vehicle owners will probably have to pay for a grid-connected HEV compared to a conventional gasoline vehicle, even if R&D targets are met. Since staff assumed continuation of existing fuel excise taxes, government would lose revenue because of fewer gallons of fuel sold, due to the assumed displacement of gasoline consumption by the grid-connected HEVs.

For consistency with other Group 2 (Fuel Substitution) options, staff assumed that grid-connected hybrid electric vehicle deployment begins in 2008. To achieve these deployment levels, however, major technical and economic breakthroughs need to occur by about 2006. These would include reducing the cost of the batteries and extending battery life.

Results

Tables 2C-1 through 2C-3 show results for grid-connected HEVs. Negative values in the table are costs either to the consumer or to the government and are shown with parentheses.

Table 2C-2 displays the results based on the midpoint fuel price. Between 2008 and 2010, with a total of 15,000 grid-connected hybrid electric vehicles operating, the results indicate that owners would pay $34 to $59 million more to operate the hybrid electric vehicles than comparable gasoline vehicles (on a net present value basis and expressed in year 2001 dollars). Correspondingly, government would lose $6 million in revenue, for net costs of $39 to $65 million. These costs grow in later years as shown in the table.

When the costs are evaluated for individual years, similar results are seen. In 2010, consumers would lose $31 to $54 million while government would lose $5 million. Net losses would total $36 to $60 million. Again, costs grow in later years.

On the other hand, grid-connected hybrid vehicles would displace 0.2 percent of the gasoline forecasted to be used by light-duty vehicles in 2010, 5.0 percent by 2020 and 9.1 percent by 2030. Displacing each gallon of gasoline using a battery-electric vehicle would cost $1.35 to $2.23 in 2010, $0.82 to $1.46 in 2020 and $0.58 to $1.11 in 2030. These dollars are in year expended, and are not on a net present value basis.

In their study, the University of Delaware calculated some value-added benefit for using grid-connected HEVs to provide A/S and other forms of grid support. However, these additional benefits are not included here because staff believes the University of Delaware cost estimates were incomplete. Furthermore, their study did not evaluate competing technologies that might provide these services at lower cost. If grid-connected HEVs are able to provide A/S and realize some value-added benefit, it is possible that a portion, or even all of the net costs reported above could be offset.

Key Drivers and Uncertainties

- There is uncertainty in the likelihood that additional research funding can reduce the cost of manufacturing advanced batteries for grid-connected hybrid electric vehicles.

- There is also uncertainty about battery life for Evs, especially if used in a grid-connected vehicle.

- There is also uncertainty in consumer interest in purchasing a grid-connected hybrid electric vehicle that would still have a higher cost compared to hybrid-electric vehicle or conventional gasoline powered vehicle. The vehicle penetration level to meet the deployment schedule used in the analysis uses a sales rate significantly higher than market survey results from EPRI's consumer market survey.[10]

- There is also uncertainty in manufacturer interest in producing grid-connected hybrid electric vehicles.

- Finally, there is uncertainty whether grid-connected HEVs could achieve additional revenue in a V-2-G application and the resulting impact on cost effectiveness over the life of the vehicle. If the V-2-G market does develop, the grid-connected hybrid electric vehicle market may develop in a more accelerated pace with lower lifecycle costs.

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[1] Society of Automotive Engineers, Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles SAE J1711 (March 1999).

[2] DOE's Hybrid Systems R&D funding was $41.8 million in Fiscal Year (FY) 2000, $49.8 million in FY 2001 and a requested $48.2 million in FY 2002.

[3] Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options, EPRI, Palo Alto, CA: 2001 1000349.

[4] Vehicle-to-Grid Power: Battery, Hybrid and Fuel Cell Vehicles as Resources for Distributed Electric Power in California, June 2001.

[5] Preproposal, Personal Electric Drive Vehicles for Vehicle-to-Grid Power: Development of Missing Parameters and User Interface, February 8, 2002.

[6] Vehicle to Grid—A Control Area Operator's Perspective, David Hawkins, California Independent System Operator, December 3, 2001.

[7] Performance and Availability of Batteries for Electric Vehicles: A Report of the Battery Technical Advisory Panel, December 11, 1995 Prepared for the California Air Resources Board.

[8] 2002—2012 Electricity Outlook Report, P700-01-004F, February 2002, Table III-2-4, adjusted to 2002 dollars.

[9] Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options, EPRI, Palo Alto, CA: 2001 1000349.

[10] Ibid.

Table 2C-1

Summary of Analysis Results

Option 2C: Grid-Connected Hybrid Electric Vehicles

Fuel Price: $1.47

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.47
Low Fuel Price Estimate ($/gallon)	$1.47

For This Option:	
Vehicle Fuel Economy (mi/kWh)	2.0
Vehicle Fuel Economy (mi/gallon)	45.0
High Incremental Cost ($ per vehicle)	$10,200
Low Incremental Cost ($ per vehicle)	$7,000
High Fuel Price ($/kWh)	$0.062
Low Fuel Price ($/kWh)	$0.062
Vehicle Life (years)	15
Discount Rate (%)	5%
Government Subsidy (Low)	
Government Subsidy (High)	

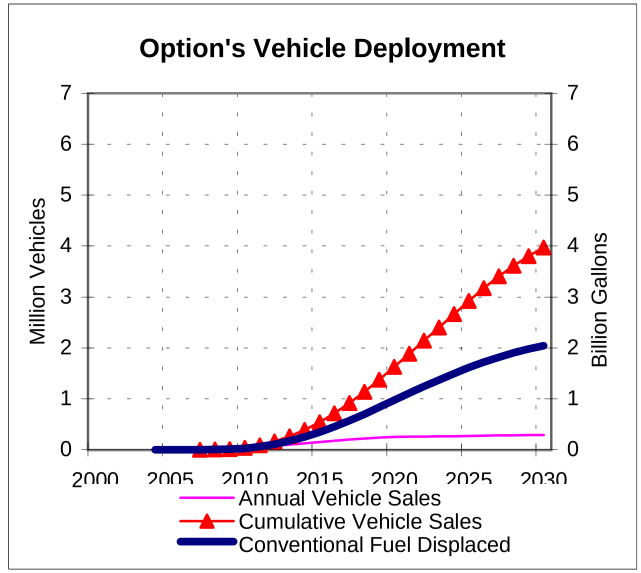
RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($55)	($29)	($6)	($6)	($60)	($35)
2002 to 2020	($2,608)	($1,154)	($433)	($433)	($3,040)	($1,587)
2002 to 2030	($7,124)	($2,749)	($1,458)	($1,458)	($8,582)	($4,207)

Single Year Savings In Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($50.1)	($26.5)	($5.4)	($5.4)	($55.5)	($31.9)
2020	($1,075)	($450)	($196)	($196)	($1,271)	($646)
2030	($1,537)	($452)	($411)	($411)	($1,948)	($863)



Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	40.3	40.3	2010	26.8	26.8	0.2%	0.2%
2002 to 2020	4,510	4,510	2020	975	975	5.0%	5.0%
2002 to 2030	20,808	20,808	2030	2,042	2,042	9.1%	9.1%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($1.87)	($0.99)	($0.20)	($0.20)	($2.07)	($1.19)
2020	($1.10)	($0.46)	($0.20)	($0.20)	($1.30)	($0.66)
2030	($0.75)	($0.22)	($0.20)	($0.20)	($0.95)	($0.42)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2C-2

Summary of Analysis Results
Option 2C: Grid-Connected Hybrid Electric Vehicles

Fuel Price: $1.64

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($59)	($34)	($6)	($6)	($65)	($39)
2002 to 2020	($2,953)	($1,498)	($433)	($433)	($3,386)	($1,931)
2002 to 2030	($8,288)	($3,907)	($1,458)	($1,458)	($9,746)	($5,365)

Single Year Savings In Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($54.4)	($30.8)	($5.4)	($5.4)	($59.8)	($36.2)
2020	($1,232)	($606)	($196)	($196)	($1,428)	($802)
2030	($1,865)	($778)	($411)	($411)	($2,276)	($1,189)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	40.3	40.3	2010	26.8	26.8	0.2%	0.2%
2002 to 2020	4,510	4,510	2020	975	975	5.0%	5.0%
2002 to 2030	20,808	20,808	2030	2,042	2,042	9.1%	9.1%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($2.03)	($1.15)	($0.20)	($0.20)	($2.23)	($1.35)
2020	($1.26)	($0.62)	($0.20)	($0.20)	($1.46)	($0.82)
2030	($0.91)	($0.38)	($0.20)	($0.20)	($1.11)	($0.58)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.64
Low Fuel Price Estimate ($/gallon)	$1.64
For This Option:	
Vehicle Fuel Economy (mi/kWh)	2.0
Vehicle Fuel Economy (mi/gallon)	45.0
High Incremental Cost ($ per vehicle)	$10,200
Low Incremental Cost ($ per vehicle)	$7,000
High Fuel Price ($/kWh)	$0.099
Low Fuel Price ($/kWh)	$0.099
Vehicle Life (years)	15
Discount Rate (%)	5%
Government Subsidy (Low)	
Government Subsidy (High)	

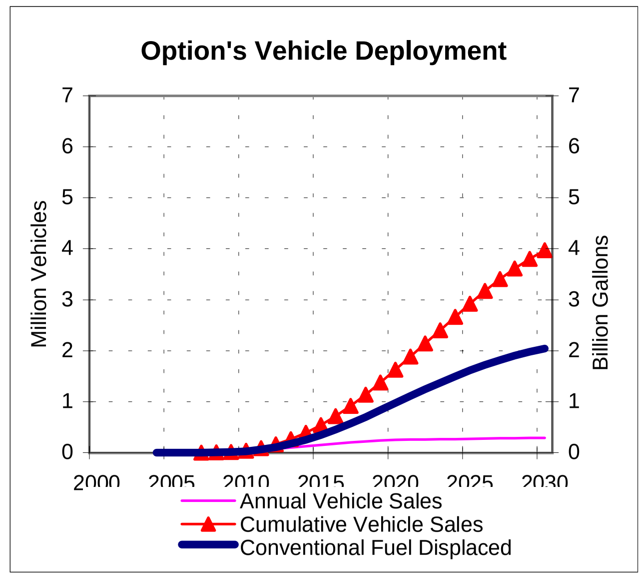


Table 2C-3

Summary of Analysis Results
Option 2C: Grid-Connected Hybrid Electric Vehicles

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($63)	($38)	($6)	($6)	($69)	($44)
2002 to 2020	($3,279)	($1,822)	($433)	($433)	($3,712)	($2,255)
2002 to 2030	($9,388)	($4,999)	($1,458)	($1,458)	($10,846)	($6,458)

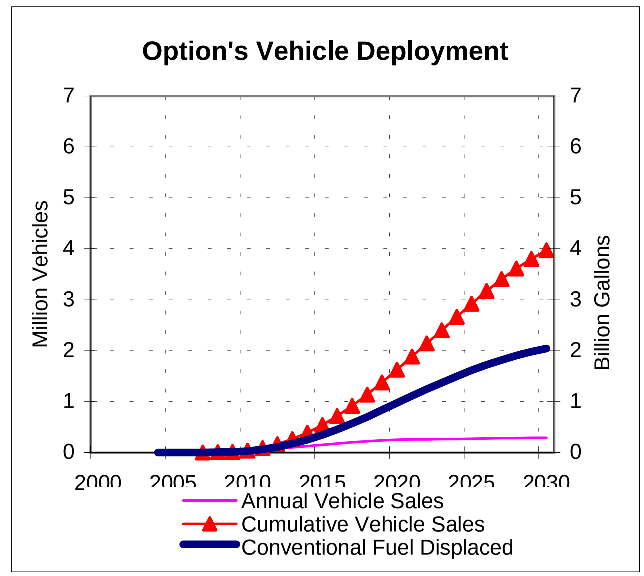
	Net Consumer Benefits					
2010	($58.5)	($34.8)	($5.4)	($5.4)	($63.9)	($40.2)
2020	($1,380)	($753)	($196)	($196)	($1,576)	($949)
2030	($2,175)	($1,086)	($411)	($411)	($2,586)	($1,497)

MAJOR INPUT ASSUMPTIONS:

Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.81
Low Fuel Price Estimate ($/gallon)	$1.81
For This Option:	
Vehicle Fuel Economy (mi/kWh)	2.0
Vehicle Fuel Economy (mi/gallon)	45.0
High Incremental Cost ($ per vehicle)	$10,200
Low Incremental Cost ($ per vehicle)	$7,000
High Fuel Price ($/kWh)	$0.135
Low Fuel Price ($/kWh)	$0.135
Vehicle Life (years)	15
Discount Rate (%)	5%
Government Subsidy (Low)	
Government Subsidy (High)	

Cumulative Over Time Period

	Low	High	Year	Low	High	Low %	High %
2002 to 2010	40.3	40.3	2010	26.8	26.8	0.2%	0.2%
2002 to 2020	4,510	4,510	2020	975	975	5.0%	5.0%
2002 to 2030	20,808	20,808	2030	2,042	2,042	9.1%	9.1%



	[1]	[2]	Low	High	[1]	[2]
2010	($2.18)	($1.30)	($0.20)	($0.20)	($2.38)	($1.50)
2020	($1.42)	($0.77)	($0.20)	($0.20)	($1.62)	($0.97)
2030	($1.07)	($0.53)	($0.20)	($0.20)	($1.27)	($0.73)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Staff Paper on Option 2D
CNG for Light-Duty Vehicles

Description

This option would provide purchase incentives for Compressed Natural Gas (CNG) light-duty vehicles and funding to support installation of public infrastructure to support a growing fleet of light-duty CNG vehicles.

Background

The National Energy Policy Act of 1990 requires certain energy providers and government fleets to purchase alternative fuel vehicles (AFV). When buying new vehicles, these fleets must currently buy 75 percent of them from alternative fuel vehicle offerings. CNG vehicles would satisfy the AFV requirement.

Status

CNG vehicles are commercially available in limited quantities and vehicle models. While there are over 400 models of gasoline vehicles offered for sale in model year 2003, there are only 8 models of CNG vehicles. Approximately 2,000 light-duty CNG vehicles are sold annually to fleet operators and private consumers in California.

A number of market barriers continue to limit the penetration of CNG vehicles in California's population of light-duty vehicles. A CNG vehicle typically has reduced driving range compared to gasoline vehicles. The relatively sparse availability of CNG refueling infrastructure accessible to the public compared to petroleum fuels further discourages private vehicle ownership. Relatively low sales volumes result in higher unit costs for CNG vehicles compared to gasoline vehicles. Fuel tanks capable of high pressure gas storage add significantly to incremental vehicle cost for CNG. These factors also reduce the number of CNG vehicle models offered by manufacturers.

The California Natural Gas Vehicle Partnership has established aggressive goals for natural gas vehicles and fuel use.[1] These goals significantly exceed values used in this analysis.

Assumptions

Staff assumed that a home refueling device is produced and manufacturers increase production of CNG vehicle models, compared to our base case. Consistent with other options, CNG light-duty vehicles displace gasoline light-duty vehicles that average 21.2 miles per gallon.

Light-duty CNG vehicles appear to be market ready at this time. Staff believes CNG vehicles will penetrate the gasoline vehicle market if fuel and other operational savings offset their more costly vehicle purchase prices. To date, this has not been the case and sales have been limited. Staff assumed that future light-duty CNG vehicles incremental costs are reduced from today's

$4,500 to $7,500 per vehicle to a lower range of $1,500 to $4,000 per vehicle. The incremental cost includes storage tanks that are estimated to cost $1,000 to $1,500. Due to the limited range associated with CNG vehicles, staff assumed the need for a home refueling unit, at an additional $1,000 per vehicle for total incremental costs of $2,500 to $5,000.

Staff developed compressed natural gas fuel costs using the following approach. First, we used the Energy Commission's commercial end-use price forecast from 2002 to 2020, adjusted with plus and minus one standard deviation (scaled to gasoline price variability) to determine a range of natural gas commodity prices, assuming commercial operation of public refueling facilities. These were $0.327 to $0.587 per therm of gas. Next, we added intrastate transportation costs and expected capital recovery for station upgrades (estimated from current natural gas utility tariffs for CNG at utility-owned public refueling stations, with scaling to account for larger volume throughput) and added expected electricity and maintenance charges, based upon existing natural gas utility tariffs. This added another $0.37 to $0.60 per therm of gas. Next, we added state and federal fuel excise taxes, sales tax and natural gas regulatory fees to arrive at final CNG price range of $1.01 to $1.55 per therm (equivalent to $1.213 to $1.852 per gallon of gasoline on an energy content basis, expressed "GGE").

Results

If the market conditions described above can be met, light-duty CNG vehicles can result in petroleum reductions as shown in Tables 2D-1 through 2D-3. Negative values in the table are costs either to the consumer or to the government and are shown with parentheses.

Table 2D-2 shows results for the midpoint fuel price. Between 2008 and 2010, with a total of 15,000 CNG vehicles operating, the results indicate that owners would pay $19 to $39 million more to operate the CNG vehicles than comparable gasoline vehicles (on a net present value basis and expressed in year 2001 dollars). Correspondingly, government would lose $6 million in revenue, for net costs of $25 to $45 million. As shown in the tables, these costs grow in later years.

When the costs are evaluated for individual years, similar results are seen. In 2010, consumers would lose $18 to $36 million while government would lose $6 million. Net losses would total $24 to $42 million. As above, these costs would grow in later years.

On the other hand, CNG vehicles would displace 0.2 percent of the gasoline forecasted to be used by light-duty vehicles in 2010, 5.7 percent by 2020 and 10.4 percent by 2030. Displacing each gallon of gasoline using a CNG vehicle would cost $0.77 to $1.37 in 2010, $0.61 to $1.04 in 2020 and $0.53 to $.89 in 2030. These dollars are in year expended, and are not on a net present value basis.

Key Drivers and Uncertainties

- There is uncertainty in the number of vehicles that consumers would purchase given that CNG vehicles have a reduced range compared to conventional gasoline powered vehicles.

- There is uncertainty in the development and production of a home-refueling device that would meet consumer needs.

- There is uncertainty in the cost of large quantities of CNG stations and uncertainty in manufacturer interest in producing additional numbers of CNG vehicles.

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[1] Natural Gas Fuels, November 2002, page 7.

Table 2D-1

Summary of Analysis Results
Option 2D: CNG for Light-Duty Vehicles

Fuel Price: $1.47

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($33)	($14)	($6)	($6)	($39)	($20)
2002 to 2020	($1,791)	($670)	($460)	($460)	($2,251)	($1,130)
2002 to 2030	($5,221)	($1,849)	($1,550)	($1,550)	($6,771)	($3,399)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($31.0)	($12.7)	($5.7)	($5.7)	($36.7)	($18.4)
2020	($760)	($277)	($209)	($209)	($968)	($486)
2030	($1,241)	($406)	($437)	($437)	($1,678)	($843)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	46.0	46.0	2010	31	31	0.2%	0.2%
2002 to 2020	5,139	5,139	2020	1,111	1,111	5.7%	5.7%
2002 to 2030	23,713	23,713	2030	2,327	2,327	10.4%	10.4%

2001 Dollars Per Gallon of Conventional Fuel Displaced

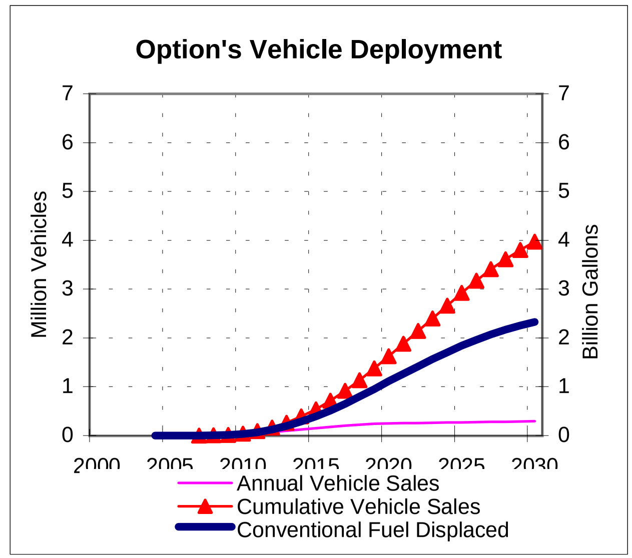
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($1.01)	($0.41)	($0.19)	($0.19)	($1.20)	($0.60)
2020	($0.68)	($0.25)	($0.19)	($0.19)	($0.87)	($0.44)
2030	($0.53)	($0.17)	($0.19)	($0.19)	($0.72)	($0.36)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.47
Low Fuel Price Estimate ($/gallon)	$1.47
For This Option:	
Vehicle Fuel Economy (mi/gallon)	20.0
High Incremental Cost ($ per vehicle)	$5,000
Low Incremental Cost ($ per vehicle)	$2,500
High Fuel Price ($/GGE)	$1.213
Low Fuel Price ($/GGE)	$1.213
Vehicle Life (years)	15
Discount Rate (%)	5%



GGE = Gallons Gasoline Equivalent

Table 2D-2

Summary of Analysis Results
Option 2D: CNG for Light-Duty Vehicles

Fuel Price: $1.64

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits [1]	Net Consumer Benefits [2]	Change in Gov't Revenue Low	Change in Gov't Revenue High	Net Benefits [1]	Net Benefits [2]
2002 to 2010	($39)	($19)	($6)	($6)	($45)	($25)
2002 to 2020	($2,205)	($1,083)	($460)	($460)	($2,665)	($1,543)
2002 to 2030	($6,615)	($3,243)	($1,550)	($1,550)	($8,165)	($4,794)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits [1]	Net Consumer Benefits [2]	Change in Gov't Revenue Low	Change in Gov't Revenue High	Net Benefits [1]	Net Benefits [2]
2010	($36.1)	($17.8)	($5.7)	($5.7)	($41.9)	($23.6)
2020	($947)	($465)	($209)	($209)	($1,156)	($674)
2030	($1,634)	($799)	($437)	($437)	($2,071)	($1,236)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated Low	High	Low %	High %
2002 to 2010	46.0	46.0	2010	31	31	0.2%	0.2%
2002 to 2020	5,139	5,139	2020	1,111	1,111	5.7%	5.7%
2002 to 2030	23,713	23,713	2030	2,327	2,327	10.4%	10.4%

2001 Dollars Per Gallon of Conventional Fuel Displaced

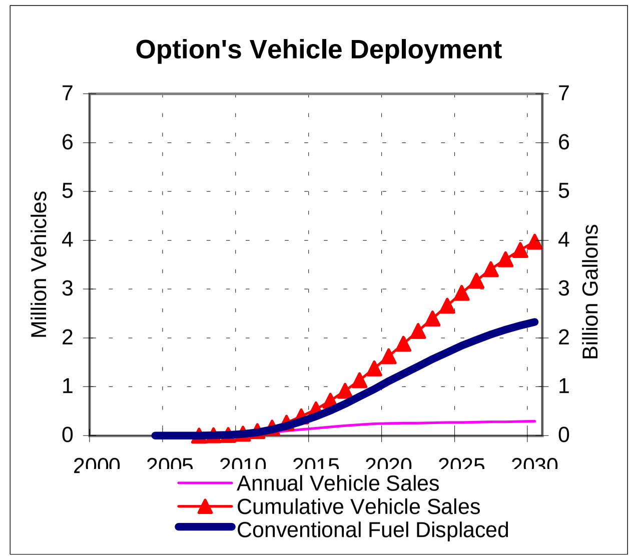
	Net Consumer Benefits [1]	Net Consumer Benefits [2]	Change in Gov't Revenue Low	Change in Gov't Revenue High	Net Benefits [1]	Net Benefits [2]
2010	($1.18)	($0.58)	($0.19)	($0.19)	($1.37)	($0.77)
2020	($0.85)	($0.42)	($0.19)	($0.19)	($1.04)	($0.61)
2030	($0.70)	($0.34)	($0.19)	($0.19)	($0.89)	($0.53)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.64
Low Fuel Price Estimate ($/gallon)	$1.64
For This Option:	
Vehicle Fuel Economy (mi/gallon)	20.0
High Incremental Cost ($ per vehicle)	$5,000
Low Incremental Cost ($ per vehicle)	$2,500
High Fuel Price ($/GGE)	$1.532
Low Fuel Price ($/GGE)	$1.532
Vehicle Life (years)	15
Discount Rate (%)	5%



GGE = Gallons Gasoline Equivalent

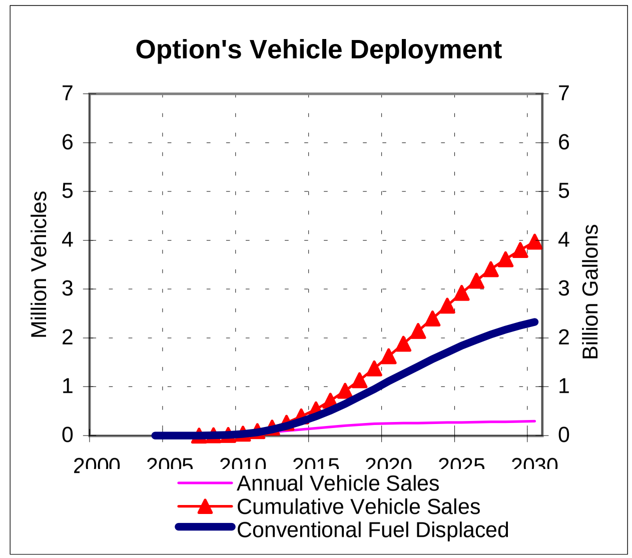
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($44)	($25)	($6)	($6)	($50)	($30)
2002 to 2020	($2,619)	($1,497)	($460)	($460)	($3,079)	($1,957)
2002 to 2030	($8,009)	($4,638)	($1,550)	($1,550)	($9,560)	($6,188)

Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.81
Low Fuel Price Estimate ($/gallon)	$1.81

Vehicle Fuel Economy (mi/gallon)	20.0
High Incremental Cost ($ per vehicle)	$5,000
Low Incremental Cost ($ per vehicle)	$2,500
High Fuel Price ($/GGE)	$1.852
Low Fuel Price ($/GGE)	$1.852
Vehicle Life (years)	15
Discount Rate (%)	5%

2010	($41.3)	($23.0)	($5.7)	($5.7)	($47.0)	($28.7)
2020	($1,135)	($653)	($209)	($209)	($1,344)	($861)
2030	($2,027)	($1,192)	($437)	($437)	($2,464)	($1,629)

	Low	High	Year	Low	High	Low %	High %
2002 to 2010	46.0	46.0	2010	31	31	0.2%	0.2%
2002 to 2020	5,139	5,139	2020	1,111	1,111	5.7%	5.7%
2002 to 2030	23,713	23,713	2030	2,327	2,327	10.4%	10.4%



	[1]	[2]	Low	High	[1]	[2]
2010	($1.35)	($0.75)	($0.19)	($0.19)	($1.54)	($0.94)
2020	($1.02)	($0.59)	($0.19)	($0.19)	($1.21)	($0.78)
2030	($0.87)	($0.51)	($0.19)	($0.19)	($1.06)	($0.70)

GGE = Gallons Gasoline Equivalent

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.
[2] This result represents the opposite of [1].

Staff Paper on Option 2E
Liquefied Petroleum Gas (LPG)

Description

This option examines the effect of liquefied petroleum gas (LPG) fuel displacing gasoline in light-duty vehicles.

Background

Propane, the major ingredient of LPG, is a colorless, odorless, tasteless and non-toxic hydrocarbon. It has a narrow flammability limit compared to gasoline, but garages and repair facilities need proper ventilation.[1] It is pressurized for use in vehicles and stored in special fuel tanks as a liquid that vaporizes to a gas before being burned in an engine. According to the Western Propane Gas Association, there were 1,200 LPG refueling facilities in California in 2001, and half of these were capable of refueling vehicles. Because of its many uses (i.e., space heating, barbecues, forklifts and recreational vehicles), refueling modest numbers of LPG vehicles can be self-sustaining with little or no government support.[2]

In California, approximately one-half of the LPG supply is a byproduct of crude oil refining and the remainder is a byproduct of removing natural gas liquids at the wellhead of gas produced in California. Even though half of California's supply derives from crude oil, staff included LPG in this analysis because it is capable of displacing gasoline and because it is a byproduct of refining crude oil, not the main product. LPG is comprised primarily of propane and butane, with small amounts of other natural gas and petroleum byproducts.

Status

LPG is one of the most widely used transportation fuels used today, except for gasoline and diesel. In 2000, there were about 268,000 LPG vehicles operating in the United states, including 33,000 in California.[3] Staff estimates this amount is over 60 percent of all operating alternative fuel vehicles that use non-petroleum fuels (excluding fuel flexible vehicles operating on gasoline). California's fleet represents about 12.3 percent of the nation's LPG vehicles. About 60 percent of the LPG vehicles are pickup trucks, taxis, buses, airort shuttles and forklifts. In 1999, about 0.4 percent of the LPG used nationwide was for transportation, while California used 3.2 percent of its LPG for transportation.[4] Nationwide in 1999, 78 percent of the LPG use was in industrial applications.

The propane supply industry indicates that four types of Original Equipment Manufacturer (OEM) vehicles are currently for sale in California:[5]

- Ford F-150 bi-fuel pickup truck (California Department of Transportation has 700-800 of them, mostly fueled with gasoline, not LPG).

- General Motors (GM) medium-duty LPG truck (these have been available for about 10 years and California sales are estimated to total about 1,000 since 1998).

- Cummins B-Series engines, which can be used in pickups and shuttle buses.

- LPG-fueled GM shuttle van, which is just now entering the market, with GM taking orders but awaiting more before launching production (as of date written).

There are currently no LPG retrofit kits certified by the California Air Resources Board for sale in California, although the industry hopes to have at least one kit certified soon and hopes to sell about 200 per year in California. Typical vehicle retrofit includes a 40 to 60 gallon tank (30 to 44 gallons gasoline equivalent) and vehicle refueling takes 3-5 minutes.

Assumptions

Staff evaluated the potential for using LPG to displace gasoline light-duty vehicles beyond those currently in use. Staff assumed OEMs offer LPG as a factory option for new light-duty vehicles. Staff assumed existing federal LPG excise taxes (13.6 cents per gallon) and state LPG excise taxes (6.0 cents per gallon) continue, and calculated excise tax revenue lost to the government and other program costs to determine total government costs.

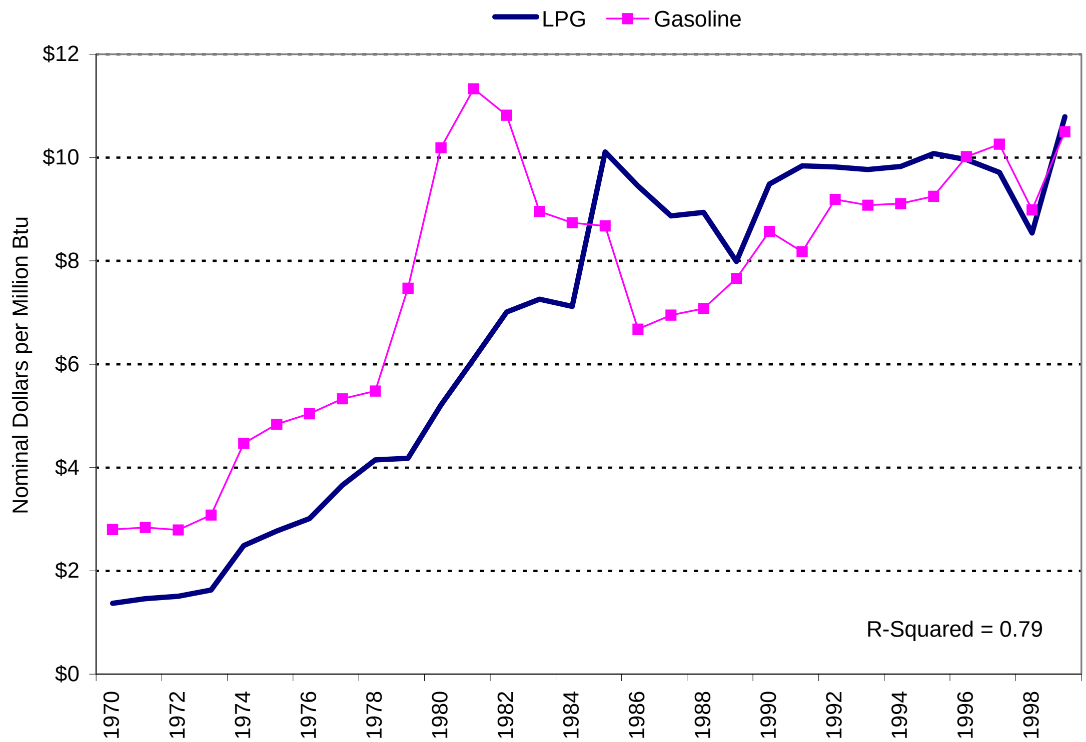
LPG fuel sales volumes and prices peak in the wintertime for space heating, and a significant transportation use would tend to level these prices out. However, if the demand grows too rapidly, existing wintertime peak prices could intensify. This analysis assumes that growth in LPG use for transportation does not cause wintertime market price peaks to intensify because a long-term import market would be established.

Historical LPG and gasoline prices track gasoline prices closely. That is, when gasoline prices are high, LPG prices are high, and visa versa. Figure 1E-1 shows California prices for LPG used in transportation and gasoline prices on an energy content basis.[6] The figure shows a fairly strong correlation (R-Squared = 0.79) between LPG and gasoline for the entire 1970 to 1999 time period, with LPG priced below gasoline until about 1984 and at parity with or above gasoline prices since 1984. Thus, staff assumed that future LPG prices would be the same as gasoline prices on an energy equivalent basis. Staff used a low LPG price of $1.11 and a high price of $1.36, based upon an energy content of 83,527 Btu per gallon, lower heating value.[7]

Adding a 6,000-gallon underground LPG tank to an existing gasoline refueling station costs about $100,000.[8] Typical existing refueling station storage tanks are 500 to 1,000 gallons, but 30,000-gallon tanks are also in use. Staff assumed the price range indicated above provides sufficient margin to absorb this cost.

Light-duty LPG vehicles have been used successfully in California and elsewhere, although there are currently only a few medium-duty OEM vehicle offerings and no light-duty OEM vehicle or retrofit kit manufacturer suppliers. Staff assumed that government incentives are sufficient to induce retrofit kit manufacturers to certify their products for use in California to allow conversion of gasoline fueled vehicles in the 2008 time period. As OEM vehicle manufacturers

Figure 1E-1: Historical California Transportation Fuel Prices
(Source: EIA Data)



see conversion kit sales increase, they make the decision to introduce new vehicles with an LPG option. The combination of retrofit kit and OEM offerings allows for vehicle deployment.

Historical vehicle conversion costs for light-duty vehicles were approximately $1,900 to $2,900 per vehicle (converted to 2001 $). Staff assumed the higher value for the high end of the incremental capital cost estimate. In large volume OEM production, staff expects the cost of making an LPG vehicle to be nearly the same as a gasoline vehicle, except the fuel storage costs would be about $200 more. This comprises the lower incremental capital cost estimate.

Results

The results of the staff analysis are shown in Tables 2E-1 to 2E-3. Negative values in the tables are costs either to the consumer or to the government and are shown with parentheses.

Table 2E-2 shows the results for the midpoint price of $1.64 per gallon of gasoline. Between 2008 and 2010, with a total of 15,000 LPG vehicles operating, the results indicate that owners would pay $2 to $23 million more to operate LPG vehicles than comparable gasoline vehicles, on a net present value basis and expressed in year 2001 dollars. Correspondingly, government would lose $0.1 million in revenue, for net costs of $2 to $23 million. As shown in the table, these costs grow in later years.

When the costs are evaluated for individual years, similar results are seen. In 2010, consumers would lose $2 to $22 million while government would lose $0.1 million. Net losses would total $2 to $22 million. Again, these costs would grow in later years.

On the other hand, LPG vehicles would displace 0.2 percent of the gasoline forecasted to be used by light-duty vehicles in 2010, 5.7 percent by 2020 and 10.4 percent by 2030. Displacing each gallon of gasoline using a LPG vehicle would cost $0.07 to $0.71 in 2010, $0.06 to $0.52 in 2020 and $0.05 to $0.44 in 2030. These dollars are in year expended, and are not on a net present value basis.

Key Drivers and Uncertainties

- The availability of new OEM vehicles.
- The availability of CARB-certified retrofit kits for light-duty vehicles.
- Government incentives must be provided so that the incremental life cycle costs are sufficiently below that of a gasoline vehicle to re-stimulate this market.

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[1] Alternative Fuels: Emissions, Economics, and Performance, Society of Automotive Engineers, Inc., page 57.

[2] Information provided by Steve Moore of Mutual Liquid Gas, and compiled by A. D. Little for the CEC's *Clean Fuels Market Assessment, 2001.*

[3] U.S. DOE, Energy Information Administration web site: http://www.eia.doe.gov/cneaf/alternate/page/datatables/table1.html.

[4] U.S. DOE, Energy Information Administration, State Energy Data Report for 1999 (latest available).

[5] Personal communication, Bill Platz, Delta Liquid Energy.

[6] Source: ftp://ftp.eia.doe.gov/pub/state.prices/html/acca.htm.

[7] An informal June 2002 survey of 12 retail stations led to a price range of $0.98 to $1.49 per gallon of LPG.

[8] California Clean Fuels Market Assessment 2001, CEC Publication P600-01-018 (September 2001).

Table 2E-1

Summary of Analysis Results
Option 2E: Liquefied Petroleum Gas (LPG)

Fuel Price: $1.47

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($23.2)	($2.0)	($0.1)	($0.1)	($23.4)	($2.1)
2002 to 2020	($1,335.9)	($124.6)	($9.6)	($9.6)	($1,345.5)	($134.2)
2002 to 2030	($4,028.9)	($387.2)	($32.4)	($32.4)	($4,061.2)	($419.6)

Single Year Savings In Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($21.7)	($1.9)	($0.1)	($0.1)	($21.8)	($2.0)
2020	($575.4)	($54.4)	($4.4)	($4.4)	($579.7)	($58.8)
2030	($1,001.8)	($99.9)	($9.1)	($9.1)	($1,010.9)	($109.0)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period			Fuel Displaced in Year Indicated				
	Low	High	Year	Low	High	Low %	High %
2002 to 2010	46.0	46.0	2010	31	31	0.2%	0.2%
2002 to 2020	5,139	5,139	2020	1,111	1,111	5.7%	5.7%
2002 to 2030	23,713	23,713	2030	2,327	2,327	10.4%	10.4%

2001 Dollars Per Gallon of Conventional Fuel Displaced

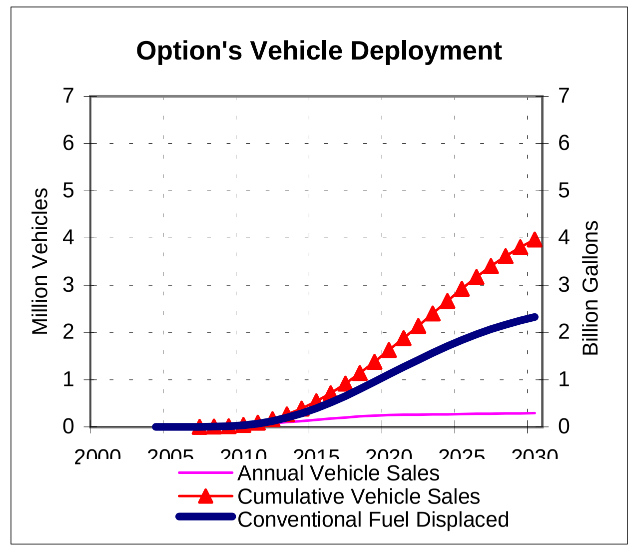
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.71)	($0.06)	($0.00)	($0.00)	($0.71)	($0.07)
2020	($0.52)	($0.05)	($0.00)	($0.00)	($0.52)	($0.05)
2030	($0.43)	($0.04)	($0.00)	($0.00)	($0.43)	($0.05)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.47
Low Fuel Price Estimate ($/gallon)	$1.47
For This Option:	
Vehicle Fuel Economy (mi/gallon)	15.8
High Incremental Cost ($ per vehicle)	$2,900
Low Incremental Cost ($ per vehicle)	$200
High Fuel Price ($/Gallon)	$1.11
Low Fuel Price ($/Gallon)	$1.11
Vehicle Life (years)	15
Discount Rate (%)	5%



GGE = Gallons Gasoline Equivalent

Table 2E-2

Summary of Analysis Results
Option 2E: Liquefied Petroleum Gas (LPG)

Fuel Price: $1.64

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($23.3)	($2.1)	($0.1)	($0.1)	($23.4)	($2.2)
2002 to 2020	($1,340)	($129)	($10)	($10)	($1,350)	($138)
2002 to 2030	($4,042)	($401)	($32)	($32)	($4,075)	($433)

Single Year Savings In Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($22)	($2)	($0)	($0)	($22)	($2)
2020	($577)	($56)	($4)	($4)	($582)	($61)
2030	($1,006)	($104)	($9)	($9)	($1,015)	($113)

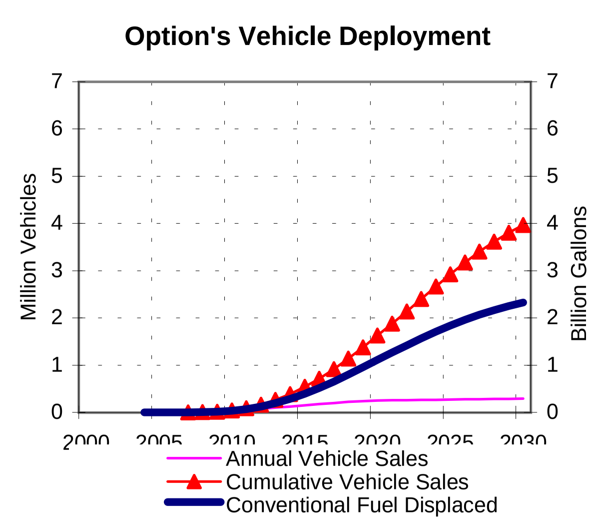
MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.64
Low Fuel Price Estimate ($/gallon)	$1.64
For This Option:	
Vehicle Fuel Economy (mi/gallon)	15.8
High Incremental Cost ($ per vehicle)	$2,900
Low Incremental Cost ($ per vehicle)	$200
High Fuel Price ($/Gallon)	$1.234
Low Fuel Price ($/Gallon)	$1.234
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	46.0	46.0	2010	31	31	0.2%	0.2%
2002 to 2020	5,139	5,139	2020	1,111	1,111	5.7%	5.7%
2002 to 2030	23,713	23,713	2030	2,327	2,327	10.4%	10.4%

(Columns Year through High % are "Fuel Displaced in Year Indicated".)



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.71)	($0.06)	($0.00)	($0.00)	($0.71)	($0.07)
2020	($0.52)	($0.05)	($0.00)	($0.00)	($0.52)	($0.05)
2030	($0.43)	($0.04)	($0.00)	($0.00)	($0.44)	($0.05)

GGE = Gallons Gasoline Equivalent

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2E-3

Summary of Analysis Results
Option 2E: Liquefied Petroleum Gas (LPG)

Fuel Price: $1.81

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($23)	($2)	($0.1)	($0.1)	($23)	($2)
2002 to 2020	($1,344)	($133)	($9.6)	($9.6)	($1,354)	($142)
2002 to 2030	($4,056)	($414)	($32.4)	($32.4)	($4,088)	($447)

Single Year Savings In Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($22)	($2)	($0.1)	($0.1)	($22)	($2)
2020	($579)	($58)	($4.4)	($4.4)	($583)	($62)
2030	($1,009)	($108)	($9.1)	($9.1)	($1,019)	($117)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
			Fuel Displaced in Year Indicated				
2002 to 2010	46.0	46.0	2010	31	31	0.2%	0.2%
2002 to 2020	5,139	5,139	2020	1,111	1,111	5.7%	5.7%
2002 to 2030	23,713	23,713	2030	2,327	2,327	10.4%	10.4%

2001 Dollars Per Gallon of Conventional Fuel Displaced

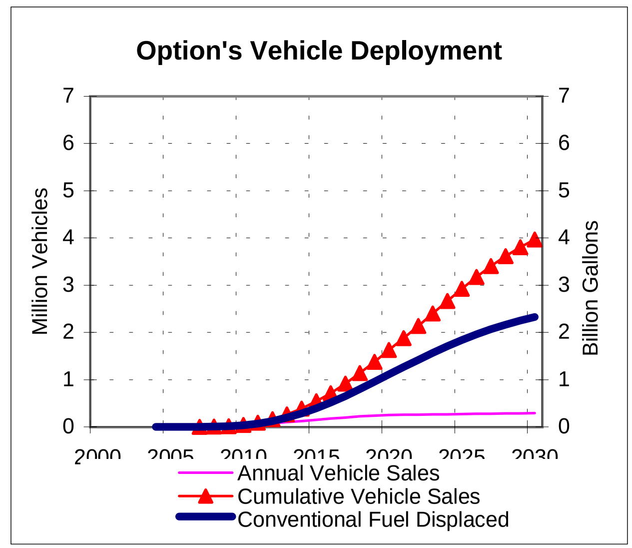
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.71)	($0.07)	($0.00)	($0.00)	($0.72)	($0.07)
2020	($0.52)	($0.05)	($0.00)	($0.00)	($0.53)	($0.06)
2030	($0.43)	($0.05)	($0.00)	($0.00)	($0.44)	($0.05)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.81
Low Fuel Price Estimate ($/gallon)	$1.81
For This Option:	
Vehicle Fuel Economy (mi/gallon)	15.8
High Incremental Cost ($ per vehicle)	$2,900
Low Incremental Cost ($ per vehicle)	$200
High Fuel Price ($/Gallon)	$1.36
Low Fuel Price ($/Gallon)	$1.36
Vehicle Life (years)	15
Discount Rate (%)	5%



GGE = Gallons Gasoline Equivalent

Staff Paper on Option 2F
Alcohol Fuels in Flexible Fuel Vehicles

Description

This strategy would involve a range of state and federal actions as well as actions by private fuel suppliers and automobile companies to significantly expand the use of alcohol based fuels in flexible fuel vehicles (FFVs).

Background

FFVs are capable of fueling with alcohol fuels (ethanol or methanol) in any combination with gasoline. While E85 and M85 are proven fuels in use today, other lower cost “FFV fuels” will likely emerge over time containing renewably based co-solvents and low value non-renewable blend stocks.

The current auto industry production of FFVs is being stimulated by Corporate Average Fuel Economy (CAFE) credits created through the federal Alternative Motor Fuels Act of 1988 (AMFA). Manufacturers are entitled to a credit against their mandated average fuel economy for all vehicle sales for sales of FFVs. A maximum credit (or CAFE average addition) of 1.2 miles per gallon is allowable for any manufacturer, a “cap” that is statutorily scheduled to diminish to 0.9 miles per gallon as of the 2004 model year. While the FFV production levels equating with the above caps cannot be precisely calculated, a general estimate is that most manufacturers would reach the cap with production of 7 to 10 percent of their entire U.S. sales volume as FFVs. To date, only the “Big Three” U.S. auto makers have marketed FFV models, with the foreign-based companies not in a CAFE-constrained position that would lead them to take advantage of the credits for FFV production.

The current FFV inroads resulting from CAFE credits adopted through AMFA represent an effective start, but cannot be considered permanent or adequate assurance of a substantial future FFV population. This outcome will require a commitment to expanded, sustained FFV production by the worldwide auto industry, most likely supported by government financial and/or regulatory inducements well beyond the production volumes assured by the existence of CAFÉ credits. Establishing the necessary fuel supplies and fueling infrastructure to make the use of alternative fuels in these vehicles practical and affordable will require further initiatives and investments by the fuel suppliers, also likely to require government inducements.

Status

All of the “Big Three” U.S. automobile manufacturers are currently building some models as standard production FFV models. California’s vehicle population now includes an estimated 120,000 ethanol FFVs produced in the 1997 through 2002 model years. About 40,000 new ethanol FFVs per year are being sold, representing about 2 percent of the state’s new vehicle market. This fleet could grow to about 400,000 vehicles by 2010.

All FFV models currently being produced are designed for use of ethanol in any combination with gasoline, up to 85 percent ethanol (E85). In past model years, FFVs designed for use of methanol and gasoline (up to M85) have also been produced and sold in California, with approximately 8,000 of these methanol FFVs estimated to still be in operation. While commercial FFV production to date has been limited to the Big Three U.S. manufacturers, eight other auto companies, including most of the major Asian and European auto makers, have provided pre-commercial FFV models for past California demonstration programs. Thus, the industry-wide technological capability for expanded FFV production appears well within reach.

Furthermore, some FFV demonstration models have been built with both ethanol and methanol fueling capability, providing evidence that future FFV models could be produced that could use either of these alcohol fuels, or even combinations of the two with gasoline. Other possible fuels for FFVs may also be developed. The "P-Series" fuel recently licensed to Pure Energy Corporation for commercial production and distribution provides one example. This fuel uses a combination of ethanol, co-solvents (potentially derived from waste biomass resources), natural gas liquids and refinery pentanes (a rejected or "distressed" blend stock not suitable for use in summertime CaRFG3). This is an EPACT designated alternative fuel which, by definition, is substantially non-petroleum.

Staff is unaware of any FFVs in California currently using alcohol fuels. Gasoline is used due to the unavailability and the relatively higher price of alcohol fuels. These FFVs could, however, use alcohol as an alternative to gasoline and they effectively constitute an insurance against sustained high gasoline prices since an alcohol fueling infrastructure could be in place quickly.

Assumptions

Staff evaluated the cost-effectiveness of using alcohol fuels in FFVs under a mature market condition. In Attachment C (Ethanol Demand and Supply Analysis) staff evaluates the maximum potential market demand for ethanol, including demand associated with maximum potential use of ethanol in FFVs.[1]

The current California FFV population and annual sales trend was developed by the Energy Commission's Transportation Modeling Program based on analysis of Department of Motor Vehicles registration records. These current inroads for FFVs were expanded to construct three future scenarios as follows.

In the analysis, FFVs fueled with E85 are assumed to get 15.9 miles per gallon of E85,[2] while the average light-duty vehicle they would displace is assumed to get 21.2 miles per gallon of gasoline. While E85 fuel is the appropriate "FFV fuel" under high gasoline displacement conditions, a "Low Cost FFV Fuel" fuel has been chosen as a more cost effective fuel under low gasoline displacement conditions.[3] FFVs fueled with Low Cost FFV Fuel are assumed to achieve 19.0 miles per gallon rather than 15.9 miles per gallon since rejected gasoline and other blend stocks that can be used in this fuel, which contains more energy per gallon relative to ethanol. Each fuel was assumed to increase fuel economy by 2.2 percent over the fuel economy expected solely from the energy content of the fuel. This factor occurs because ethanol in the fuel enhances combustion.

In a mature market, FFV production is assumed to lead to industry-wide levels that result in 10 percent of the state's vehicle population using FFV fuels by 2020, or about 3 million of the 30 million vehicles projected to be in use by that year. By 2030, the population increases to 30 percent of the FFV population, with FFV fueled vehicles accounting for 11 million of the state's projected 36 million vehicles.

Gasoline displaced by FFV fuel using vehicles is based on an assumption that they will use Low Cost FFV Fuel or E85 when they refuel. The amount of gasoline displaced in the low case is equivalent to the number of vehicles using Low Cost FFV Fuel 100 percent of the time. The high case is based upon the FFVs using E85 fuel 100 percent of the time. To be consistent with other Fuel Substitution options, we assumed only a limited number of vehicles would fuel with the FFV fuel, with conventional gasoline used the remainder of the time. See Attachment A (Methodology) for a discussion of vehicle deployment rate.

FFV fuel costs were assumed to be the same as gasoline on an energy equivalent basis. However, if the "distressed blend stock" cannot be absorbed by other energy or chemical markets, refiners may choose to sell the distressed blend stock at low prices and the resulting Low Cost FFV fuel may become less expensive than gasoline, even on an energy equivalent basis. Such evaluation was beyond the scope of this analysis.

Results

The results of the analysis are shown in Tables 2F-1 through 2F-3 for Low Cost FFV Fuel (Low Case) and Tables 2F-4 through 2F-6 for E85 (High Case).

The results at the midpoint fuel price are displayed in Tables 2F-2 and 2F-5. Between 2008 to 2010, with a total of 15,000 vehicles operating on FFV fuel, results indicate that owners would either save $0.6 million in the low case or spend an extra $1 million in the high case (on a net present value basis and expressed in year 2001 dollars). Correspondingly, government would lose $3 to $8 million in revenue for net losses of $2.5 million to $9 million. These values grow in later years as shown in the tables.

When the costs are evaluated for individual years, similar results are seen. In 2010, consumers would either save $0.6 million or spend an extra $1 million while government would lose $3 to $8 million. Net results would range from a loss of $2.5 to $9 million. Again, costs would grow in later years.

On the other hand, the FFV fuel would displace 0.1 percent of the gasoline forecasted to be used by light-duty vehicles in 2010, 3.1 to 4.2 percent by 2020 and 5.7 to 7.7 percent by 2030. Displacing each gallon of gasoline using FFV fuel would cost $0.15 to $0.37 per gallon for 2010, 2020 and 2030. These dollars are in year expended, and are not on a net present value basis.

Key Drivers and Uncertainties

Major factors that will determine the actual potential for FFVs to displace petroleum in California are:

- Availability of E85 and Low Cost FFV fuels at fuel prices sufficiently below gasoline to cause consumers to seek out and use these fuels.[4]

- The federal government's action regarding continuing, revising or rescinding the CAFE credit for production of FFVs.

- Possible emergence of other stimuli that may foster increased auto industry FFV production, including FFV offerings by foreign manufacturers and overall industry production at market penetration levels beyond those induced by the CAFE credits.

- FFV marketing decisions specific to California, including manufacturers electing to pursue emission certification and California marketing of all FFV models; also, the extent to which state and federal air quality regulatory approaches support (or accommodate) FFVs.

- The extent to which the above factors combine to produce a sufficient "critical mass" FFV population in the state to warrant necessary investments in fueling infrastructure by oil companies and independent distributors.

- The extent to which large fleet owners of FFVs (including both private fleets and publicly owned fleets such as the state government fleet) elect to lead the way by establishing E85 or other FFV fuel use practices.

- Progress in the development of processes and projects for producing alcohol fuels, in-state, nationally and internationally from cellulosic resources.

- The comparative market economics of ethanol and gasoline, as affected by government incentives and tax policies, including possible revision to the current federal tax incentives which provide greater market impetus for ethanol/gasoline blending than for E85 distribution.

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[1] Even though not formally evaluated, this scenario is quite feasible given the maturity and low costs of components required to make a vehicle an "FFV" when compared to all other options in the Task 3 analysis. This case would yield reductions in base case petroleum demand up to 81 percent (2030) assuming E85 as the FFV fuel of choice. Attachment C, titled "Ethanol Demand and Supply Analysis", discusses sources of ethanol to meet demand implied in this option and Option 2G (Use of Ethanol in California Reformulated Gasoline). The analysis contained in Attachment C indicates sufficient ethanol from a combination of in-state, Midwest, Pacific Northwest and foreign production to meet the ethanol demand for both options combined.

[2] This FFV fuel is comprised of 85 percent ethanol and 15 percent CaRFG3.

[3] This FFV fuel is comprised of 30 percent ethanol, 35 percent non-petroleum or renewable blend stocks and 35 percent CaRFG3 and/or other low cost or rejected gasoline blending components.

[4] The economic analysis assumes fuel price parity on an energy equivalent basis.

Table 2F-1

Summary of Analysis Results

Option 2F: Alcohol Fuels in Flexible Fuel Vehicles

Case: Low Gasoline Displacement; Fuel Price: $1.47

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
For Correlated Fuel Prices:	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$0.6	$0.6	($3.1)	($3.1)	($2.6)	($2.6)
2002 to 2020	$44	$44	($243)	($243)	($198)	($198)
2002 to 2030	$149	$149	($818)	($818)	($669)	($669)

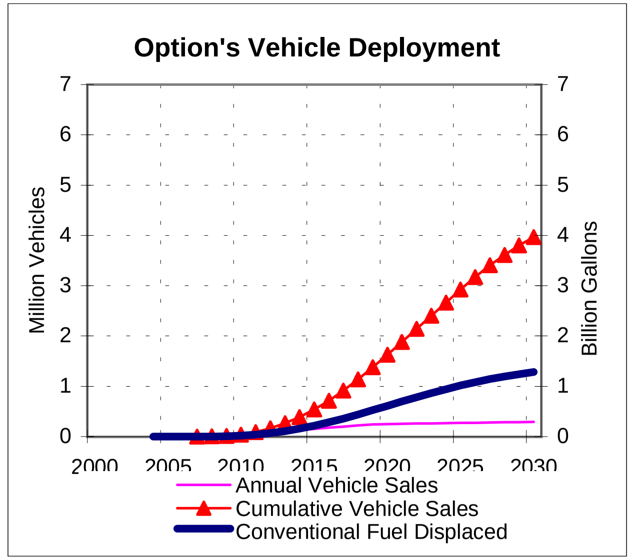
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$0.6	$0.6	($3.0)	($3.0)	($2.5)	($2.5)
2020	$20.1	$20	($110.1)	($110.1)	($90.0)	($90.0)
2030	$42.0	$42	($230.5)	($230.5)	($188.5)	($188.5)

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.47
Low Fuel Price Estimate ($/gallon)	$1.47
For This Option:	
Vehicle Fuel Economy (mi/gallon)	19.0
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.298
Low Fuel Price ($/Gallon)	$1.298
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
			Fuel Displaced in Year Indicated				
2002 to 2010	25.3	25.3	2010	17	17	0.1%	0.1%
2002 to 2020	2,834	2,834	2020	613	613	3.1%	3.1%
2002 to 2030	13,076	13,076	2030	1,283	1,283	5.7%	5.7%



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.03	$0.03	($0.18)	($0.18)	($0.15)	($0.15)
2020	$0.03	$0.03	($0.18)	($0.18)	($0.15)	($0.15)
2030	$0.03	$0.03	($0.18)	($0.18)	($0.15)	($0.15)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2F-2

Summary of Analysis Results

Option 2F: Alcohol Fuels in Flexible Fuel Vehicles

Case: Low Gasoline Displacement; Fuel Price: $1.64

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
For Correlated Fuel Prices:	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$0.6	$0.6	($3.1)	($3.1)	($2.5)	($2.5)
2002 to 2020	$49	$49	($243)	($243)	($193)	($193)
2002 to 2030	$166	$166	($818)	($818)	($651)	($651)

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$0.6	$0.6	($3.0)	($3.0)	($2.4)	($2.4)
2020	$22.4	$22	($110.1)	($110.1)	($87.7)	($87.7)
2030	$46.9	$47	($230.5)	($230.5)	($183.6)	($183.6)

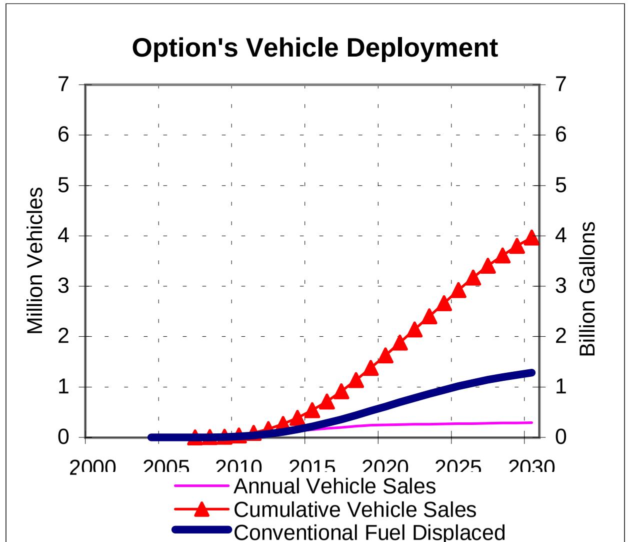
MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.64
Low Fuel Price Estimate ($/gallon)	$1.64
For This Option:	
Vehicle Fuel Economy (mi/gallon)	19.0
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.45
Low Fuel Price ($/Gallon)	$1.45
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	25.3	25.3	2010	17	17	0.1%	0.1%
2002 to 2020	2,834	2,834	2020	613	613	3.1%	3.1%
2002 to 2030	13,076	13,076	2030	1,283	1,283	5.7%	5.7%

(Low/High under "Year" columns: Fuel Displaced in Year Indicated)



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.04	$0.04	($0.18)	($0.18)	($0.14)	($0.14)
2020	$0.04	$0.04	($0.18)	($0.18)	($0.14)	($0.14)
2030	$0.04	$0.04	($0.18)	($0.18)	($0.14)	($0.14)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2F-3

Summary of Analysis Results

Option 2F: Alcohol Fuels in Flexible Fuel Vehicles

Case: Low Gasoline Displacement; Fuel Price: $1.81

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
For Correlated Fuel Prices:	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$1	$1	($3)	($3)	($2)	($2)
2002 to 2020	$54	$54	($243)	($243)	($188)	($188)
2002 to 2030	$184	$184	($818)	($818)	($634)	($634)

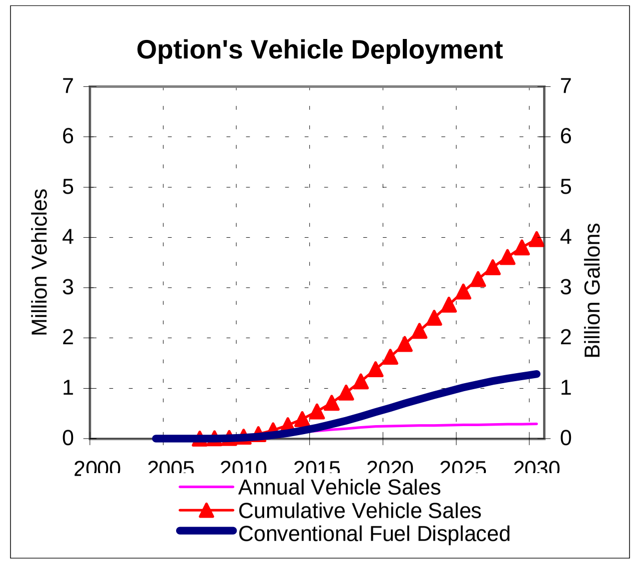
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$0.7	$1	($3.0)	($3.0)	($2.3)	($2.3)
2020	$24.7	$25	($110.1)	($110.1)	($85.4)	($85.4)
2030	$51.8	$52	($230.5)	($230.5)	($178.8)	($178.8)

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.81
Low Fuel Price Estimate ($/gallon)	$1.81
For This Option:	
Vehicle Fuel Economy (mi/gallon)	19.0
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.60
Low Fuel Price ($/Gallon)	$1.60
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	25.3	25.3	2010	17	17	0.1%	0.1%
2002 to 2020	2,834	2,834	2020	613	613	3.1%	3.1%
2002 to 2030	13,076	13,076	2030	1,283	1,283	5.7%	5.7%



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.04	$0.04	($0.18)	($0.18)	($0.14)	($0.14)
2020	$0.04	$0.04	($0.18)	($0.18)	($0.14)	($0.14)
2030	$0.04	$0.04	($0.18)	($0.18)	($0.14)	($0.14)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2F-4

Summary of Analysis Results

Option 2F: Alcohol Fuels in Flexible Fuel Vehicles

Case: High Gasoline Displacement; Fuel Price: $1.47

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($0.7)	($0.7)	($8)	($8)	($9)	($9)
2002 to 2020	($22)	($22)	($635)	($635)	($658)	($658)
2002 to 2030	($43)	($43)	($2,140)	($2,140)	($2,183)	($2,183)

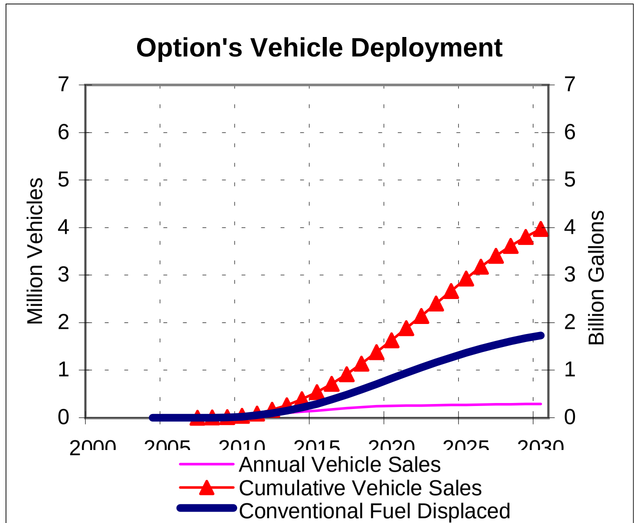
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($0.6)	($0.6)	($7.9)	($7.9)	($8.5)	($8.5)
2020	($8.0)	($8.0)	($288.1)	($288.1)	($296.1)	($296.1)
2030	($2.8)	($2.8)	($603.4)	($603.4)	($606.3)	($606.3)

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.47
Low Fuel Price Estimate ($/gallon)	$1.47
For This Option:	
Vehicle Fuel Economy (mi/gallon)	15.9
High Incremental Cost ($ per vehicle)	$200
Low Incremental Cost ($ per vehicle)	$200
High Fuel Price ($/Gallon)	$1.081
Low Fuel Price ($/Gallon)	$1.081
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	34.1	34.1	2010	23	23	0.1%	0.1%
2002 to 2020	3,818	3,818	2020	825	825	4.2%	4.2%
2002 to 2030	17,615	17,615	2030	1,729	1,729	7.7%	7.7%



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.03)	($0.03)	($0.35)	($0.35)	($0.38)	($0.38)
2020	($0.01)	($0.01)	($0.35)	($0.35)	($0.36)	($0.36)
2030	($0.00)	($0.00)	($0.35)	($0.35)	($0.35)	($0.35)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2F-5

Summary of Analysis Results

Option 2F: Alcohol Fuels in Flexible Fuel Vehicles

Case: High Gasoline Displacement; Fuel Price: $1.64

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($1)	($1)	($8)	($8)	($9)	($9)
2002 to 2020	($15)	($15)	($635)	($635)	($650)	($650)
2002 to 2030	($17)	($17)	($2,140)	($2,140)	($2,157)	($2,157)

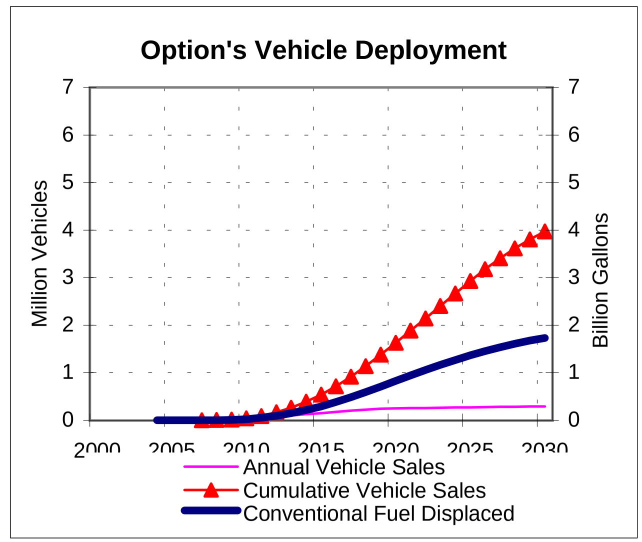
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($1)	($1)	($8)	($8)	($8)	($8)
2020	($5)	($5)	($288)	($288)	($293)	($293)
2030	$5	$5	($603)	($603)	($599)	($599)

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.64
Low Fuel Price Estimate ($/gallon)	$1.64
For This Option:	
Vehicle Fuel Economy (mi/gallon)	15.9
High Incremental Cost ($ per vehicle)	$200
Low Incremental Cost ($ per vehicle)	$200
High Fuel Price ($/Gallon)	$1.21
Low Fuel Price ($/Gallon)	$1.21
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	34.1	34.1	2010	23	23	0.1%	0.1%
2002 to 2020	3,818	3,818	2020	825	825	4.2%	4.2%
2002 to 2030	17,615	17,615	2030	1,729	1,729	7.7%	7.7%



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.02)	($0.02)	($0.35)	($0.35)	($0.37)	($0.37)
2020	($0.01)	($0.01)	($0.35)	($0.35)	($0.35)	($0.35)
2030	$0.00	$0.00	($0.35)	($0.35)	($0.35)	($0.35)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2F-6

Summary of Analysis Results

Option 2F: Alcohol Fuels in Flexible Fuel Vehicles

Case: High Gasoline Displacement; Fuel Price: $1.81

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($0.5)	($0.5)	($8)	($8)	($9)	($9)
2002 to 2020	($7)	($7)	($635)	($635)	($642)	($642)
2002 to 2030	$10	$10	($2,140)	($2,140)	($2,131)	($2,131)

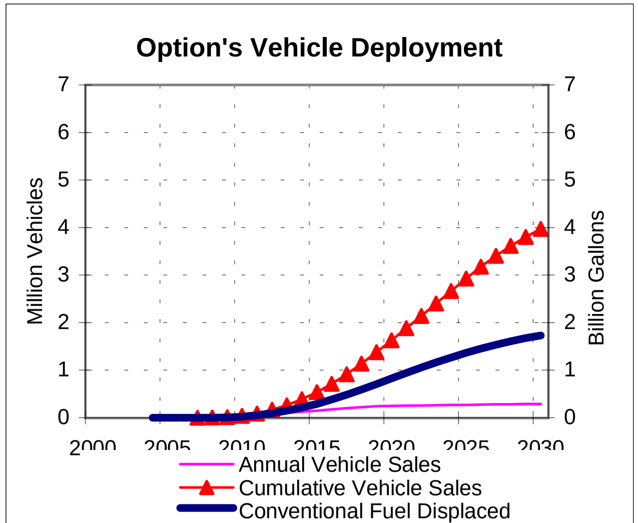
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($0.4)	($0.4)	($7.9)	($7.9)	($8.3)	($8.3)
2020	($1.0)	($1.0)	($288.1)	($288.1)	($289.1)	($289.1)
2030	$12.0	$12.0	($603.4)	($603.4)	($591.5)	($591.5)

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.81
Low Fuel Price Estimate ($/gallon)	$1.81
For This Option:	
Vehicle Fuel Economy (mi/gallon)	15.9
High Incremental Cost ($ per vehicle)	$200
Low Incremental Cost ($ per vehicle)	$200
High Fuel Price ($/Gallon)	$1.33
Low Fuel Price ($/Gallon)	$1.33
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	34.1	34.1	2010	23	23	0.1%	0.1%
2002 to 2020	3,818	3,818	2020	825	825	4.2%	4.2%
2002 to 2030	17,615	17,615	2030	1,729	1,729	7.7%	7.7%



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.02)	($0.02)	($0.35)	($0.35)	($0.37)	($0.37)
2020	($0.00)	($0.00)	($0.35)	($0.35)	($0.35)	($0.35)
2030	$0.01	$0.01	($0.35)	($0.35)	($0.34)	($0.34)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Staff Paper on Option 2G
Use of Ethanol in California Reformulated Gasoline

Description

This option addresses increased use of ethanol in California Phase 3 reformulated gasoline (CaRFG3) at greater percentages than the base case.

Background

Under existing regulations, refiners can blend from zero to ten percent ethanol as a substitute for Methyl Tertiary Butyl Ether (MTBE). Initially, refiners are expected to blend 5.7 percent ethanol, as MTBE is phased-out of gasoline by December 31, 2003.

The option of 10 percent ethanol in gasoline is desirable from a petroleum displacement perspective, since a nominal 4.3 percent additional ethanol could be blended into the gasoline pool. Blending beyond 5.7 percent ethanol may enable gasoline pool "swelling" as well.[1] Some analysts expect that there would need to be shrinkage rather than swelling and both are excluded from this analysis.

Currently, CaRFG3 requires a minimum of 5.7 percent by volume ethanol to meet a federally mandated 2-weight percent oxygen content requirement for federal non-attainment areas. Likewise, under current rules, refiners are allowed to use up to 3.7 weight percent oxygen corresponding to 10 volume percent when using ethanol. Blending at this volume yields the full value (i.e. 5.3 cents per gallon gasoline) of a 53 cent per gallon (ethanol blended) federal fuel excise tax forgiveness under current federal tax law.

Status

Blending greater volumes of ethanol, up to a maximum of 10 percent ethanol by volume, is allowable under the Air Resources Board Predictive Model, but would cost more than a 5.7 percent ethanol in gasoline when ethanol is more expensive than gasoline or lower cost substitute hydrocarbons. If ethanol is available at lower cost than substitute hydrocarbons or gasoline, refiners will prefer to blend at 10 volume percent since this would lower the cost of making gasoline and increase their profit margin.[2] To blend at 10 percent ethanol currently, refiners would have to change some fuel properties to offset emissions impacts associated with higher oxygen levels, in order to comply with the CaRFG3 Predictive Model emission performance criteria. This could decrease the volume of complying fuel produced and may require the refiner to blend at less than the desired 10 volume percent in order to achieve vehicle emissions no greater than those for the base case gasoline (CaRFG3).

Current emissions data for existing vehicle classes in the Air Resources Board's Predictive Model show that 10 percent ethanol blends would cause an increase of Oxides of Nitrogen (NOx), when compared to blends using 5.7 percent ethanol. In the existing model, adding oxygen to fuel tends to decrease carbon monoxide and hydrocarbon emissions but has the undesirable impact of increasing NOx emissions. It is possible that these effects could diminish as advanced technology vehicles are deployed in the fleet.

Assumptions

In this option, the term "5.7 percent ethanol" represents the expected practice of blending the minimum amount of ethanol required to meet requirements in clean fuel regulations. The term "10 percent ethanol" represents a future potential practice of blending the maximum amount of ethanol allowed. Staff assumed that refinery economics remain favorable at 10 volume percent level and that emissions benefits of currently envisioned CaRFG3 using 5.7 percent ethanol are retained. Thus a nominal 4.3 volume percent increase in ethanol content is assumed for the analysis relative to the base case CaRFG3.

Staff did not determine how many years of new vehicle technology are needed to penetrate the fleet of on-road vehicles enough to significantly change overall vehicle pollutant emissions sufficiently. New emissions data from future vehicles would need to be added to the Predictive Model database and revised coefficients relating NOx emissions to fuel properties derived. Since older vehicles are so much more polluting than these new technology vehicles, emissions from them will tend to dominate the overall mix of pollutants even as they are driven fewer miles per year. Staff assumed that eventually the fleet turnover should make it more feasible for refiners to make 10 percent ethanol blends within the limits of an updated Predictive Model.

This analysis is limited to the petroleum reduction and cost impacts of a 10 percent ethanol blend, which might be possible at some future time. For purposes of this evaluation, staff assumed that automobile manufacturers would continue to improve fuel systems and emission controls in passenger cars and light trucks consistent with emissions standards adopted under California regulations. Vehicles would need to drive and perform well on a CaRFG3 E-10 gasoline while achieving LEV II and post LEV II emissions standards. In addition, vehicle manufacturers would be expected to retain their current practice and warranty policy explicitly allowing use of 10 percent ethanol in gasoline.

To meet future state evaporative emission requirements automobile manufacturers are reducing evaporative and permeation emissions through use of improved fuel system materials along with evolving emissions and flexible engine/fuel vapor control systems. These systems are anticipated to allow the use of any level of oxygen in gasoline up to at least 10 percent ethanol content by volume.[3] Thus, for this option, staff assumed zero incremental vehicle capital cost associated with the use of E-10 CaRFG.

Staff further assumed that the Air Resources Board's Predictive Model will be revised in 2005 and in 2010, consistent with the ARB regulatory timetable to incorporate new emissions data from future passenger cars and light-duty trucks. These new data will be needed to characterize future vehicle fleet emissions as influenced by fuel properties given then existing advanced fuel systems and emissions controls. Staff also assumes that resulting adjustments in the Predictive Model would create additional "blending space" for refiners and thus make it easier to offset any increases in hydrocarbon, carbon monoxide, toxic emissions and ozone forming potential by altering one or more fuel properties while increasing oxygen level.

Regarding ethanol fuel supply to meet increased ethanol demand associated with 10 percent ethanol blending in California, staff assumed that new ethanol plants would continue to be built in the United States in response to increased market demand. Staff expects this demand to continue to increase, with the phase-out of MTBE nationwide and the establishment of a federal "renewable fuel standard," when and if enacted by Congress.

Most of this ethanol supply will be located in the U. S. Mid-West and transported to California by marine tanker or by rail. In addition, staff assumed that California's farmers and agri-businesses will establish a base of conventional ethanol production on up to one million acres of irrigated land now dedicated to crops that provide marginal returns and that can be grown elsewhere in the world at lower cost. This conventional ethanol base is assumed to be augmented increasingly in the out years by waste-biomass derived ethanol from a multiplicity of in-state forest, agricultural and urban waste sources.

Staff assumes that a growing demand for ethanol can be met with a combination of California ethanol production, importation of ethanol from the Midwest, Pacific Northwest, and foreign sources. Production levels and imports would meet not only needs for a 10 percent ethanol blending in gasoline, but also the increasing use of ethanol in Flexible Fueled Vehicles (discussed in Option 2F). A combined demand and supply analysis for these two options can be found in Attachment C.

Staff estimates the cost to blend gasoline containing 10 percent ethanol to be higher than the cost to blend 5.7 percent ethanol in gasoline based on historical relationships of ethanol and gasoline prices. Ethanol prices are assumed to track gasoline prices, and a federal tax credit currently at 52 cents per gallon of ethanol blended (into gasoline) partially offsets the increased fuel cost to consumers. The federal tax credit shifts a portion of the costs from consumers to the federal government. Staff further assumed that fueling, storage and distribution infrastructure in place to serve a 5.7 percent blend market would be adequate to serve a 10 percent ethanol/gasoline market as well.[4] This cost analysis is conservative in that it does not reflect downward fluctuations in the market price of ethanol relative to gasoline, a recent trend which currently puts the cost of ethanol blending in gasoline lower than the cost of blending MTBE.[5]

This result presumes that the logistics of supplying 10 percent by volume ethanol are no greater a challenge than providing the expected 5.7 percent by volume ethanol. It also presumes that sufficient ethanol supply exists, and that the in-state logistics of ethanol transport and dispatching at the terminal rack for supplying 10 percent volume ethanol are accommodated in current planning for use of 5.7 percent ethanol in gasoline. We assume that the changeover to 10 percent occurs January 1, 2008.

Results

Tables 2G-1 through 2G-3 display the results of this analysis. Greater use of ethanol as an oxygenate in gasoline for conventional vehicles (moving from 5.7 percent up to 10 percent) is a fuel supply alternative that is especially sensitive to the fuel supply and price relationship used to forecast the base case gasoline demand. Without a usable estimate for the supply and price impact on base case gasoline due to this option, the end-use and demand-side methods used in this analysis can greatly under-predict the consumer benefit for this option. Negative values in the tables are costs either to the consumer or to the government and are shown with parentheses.

Table 2G-2 shows results for the midpoint gasoline price of $1.64 per gallon. Between 2008 and 2010, the results indicate that owners would pay no more to operate their vehicles than using 5.7 volume percent gasoline. Government, however, would lose $0.8 billion in revenue due to the effects of the federal ethanol subsidy. As shown in the table, these costs grow in later years.

When the costs are evaluated for individual years, similar results are seen. In 2010, consumers would pay no more but government would lose $376 million. Net losses would be limited to government losses. Again, costs grow in later years.

On the other hand, use of 10 percent ethanol in place of 5.7 percent ethanol in gasoline would displace 4.3 percent of the gasoline forecasted to be used by light-duty vehicles in the 2010 to 2030 time period. Displacing each gallon of gasoline would cost $0.51 per gallon. These dollars are in year expended, and are not on a net present value basis.

Key Drivers and Uncertainties

Major factors that will determine the actual potential for using increased volumes of ethanol to displace gasoline in California are:

- The availability of ethanol to serve the increased demand without adversely impacting ethanol price and fuel prices.

- The willingness of auto manufacturers to continue to develop fuel and emission control systems that will allow operation at 10 percent ethanol in CaRFG3, while retaining desirable emissions and vehicle performance characteristics.

- The adoption of a federal renewable fuel standard, which would assure adequate supplies with minimal price volatility, as the in-state ethanol production industry develops.

- The assumption that new cars and light truck emission performance will offset much or all of the current NOx emissions penalty estimated for Technology 5 class vehicles and reflected in the current Predictive Model for CaRFG3 with oxygen content in excess of 2.0 weight percent.

- The outcome of California's request for waiver from the oxygen requirements in the CAA, creation of a nationwide renewable fuels standard (RFS) with a regional RFS credit trading option, MTBE bans in other states, other states' incentives for ethanol production and use in gasoline, and a nationwide MTBE ban will affect individual refiner's approach and level of ethanol blending in CaRFG3.

[1] "Pool swelling" for purposes of this analysis is defined as a net increase in gasoline blending components available for making CaRFG3 for a given volume of crude oil input to the refinery. Refinery blending practices indicate that between 1 and 4 volume percent extra hydrocarbons can be blended into reformulated blendstock for oxygenate blending when the ethanol content is raised from 5.7 to 10 percent. Pool swelling means more crude oil is processed into gasoline by retaining blendstocks that would otherwise be rejected as unsuitable for gasoline blending at the lower oxygenate blending volume. In this analysis, staff were not able to evaluate the effect.

[2] Barber et. al., "Motor Gasolines Technical Review", Document FTR1, Chevron Products Company, 1996.

[3] Some auto industry engineers believe that 15 percent ethanol in gasoline in today's new passenger cars and light trucks is a fuel that could provide consumers with performance and vehicle drive characteristics indistinguishable from conventional and reformulated gasoline containing lower levels or no ethanol. By design, the entire fleet of gasoline vehicles in Brazil operates on gasoline containing between 22 and 24 percent ethanol. Thus, higher ethanol blend levels are demonstrably real thus suggesting the possibility of more aggressive ethanol-in-gasoline scenarios not included in the present analysis.

[4] Discussions with several oil companies indicate that terminal storage of ethanol involves tanks sized to assure adequate inventories of ethanol given somewhat unpredictable movement of ethanol from the Midwest and the long transport distances involved. Future in-state ethanol production combined with the excess ethanol inventory capability now in place for MTBE phase-out at the end of 2003, and assumed improvements ine thanol transport modes (e.g. unit trains) likely to occur in 2003 and 2004 is assumed to make 10 percent ethanol blending viable with no new capital cost expenditures.

[5] Recent contract ethanol (6/02) delivered to California is estimated at about $1.15 per gallon. The federal fuel excise tax forgiveness (52 cents per gallon of ethanol) lowers the cost of ethanol to 63 cents per gallon for blenders (refiners). MTBE wholesale price in June 2002 was about 97 cents per gallon and CaRFG wholesale price was about $1.00 per gallon.

Table 2G-1

Summary of Analysis Results
Option 2G: Use of Ethanol in California Reformulated Gasoline

Fuel Price: $1.47

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits [1]	Net Consumer Benefits [2]	Change in Gov't Revenue Low	Change in Gov't Revenue High	Net Benefits [1]	Net Benefits [2]
2002 to 2010	($714)	($714)	($779)	($779)	($1,493)	($1,493)
2002 to 2020	($2,654)	($2,654)	($2,893)	($2,893)	($5,548)	($5,548)
2002 to 2030	($4,015)	($4,015)	($4,377)	($4,377)	($8,392)	($8,392)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($345)	($345)	($376)	($376)	($721)	($721)
2020	($395)	($395)	($431)	($431)	($826)	($826)
2030	($454)	($454)	($494)	($494)	($948)	($948)

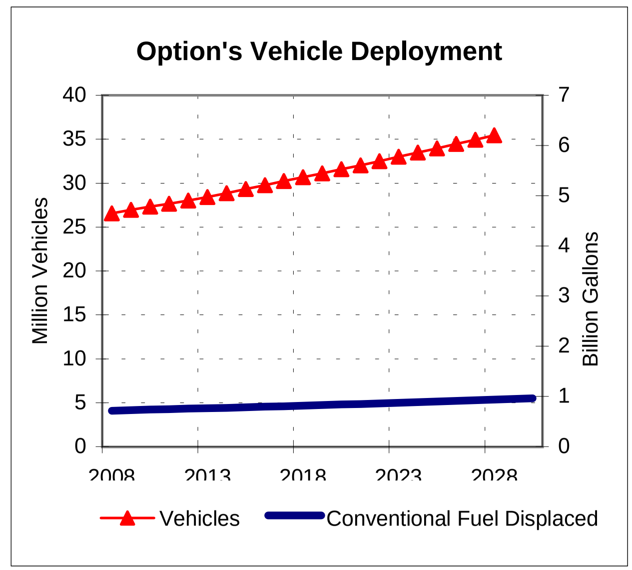
MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.47
Low Fuel Price Estimate ($/gallon)	$1.47

For This Option:	
Vehicle Fuel Economy (mi/gallon)	20.9
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.47
Low Fuel Price ($/Gallon)	$1.47
Vehicle Life (years)	15
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated Low	High	Low %	High %
2002 to 2010	2,180	2,180	2010	737	737	4.3%	4.3%
2002 to 2020	10,087	10,087	2020	839	839	4.3%	4.3%
2002 to 2030	19,146	19,146	2030	963	963	4.3%	4.3%



GGE = Gallons Gasoline Equivalents

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits [1]	Net Consumer Benefits [2]	Change in Gov't Revenue Low	Change in Gov't Revenue High	Net Benefits [1]	Net Benefits [2]
2010	($0.47)	($0.47)	($0.51)	($0.51)	($0.98)	($0.98)
2020	($0.47)	($0.47)	($0.51)	($0.51)	($0.98)	($0.98)
2030	($0.47)	($0.47)	($0.51)	($0.51)	($0.98)	($0.98)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2G-2

Summary of Analysis Results
Option 2G: Use of Ethanol in California Reformulated Gasoline

Fuel Price: $1.64

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$0	$0	($779)	($779)	($779)	($779)
2002 to 2020	$0	$0	($2,893)	($2,893)	($2,893)	($2,893)
2002 to 2030	$0	$0	($4,377)	($4,377)	($4,377)	($4,377)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$0	$0	($376)	($376)	($376)	($376)
2020	$0	$0	($431)	($431)	($431)	($431)
2030	$0	$0	($494)	($494)	($494)	($494)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	2,180	2,180	2010	737	737	4.3%	4.3%
2002 to 2020	10,087	10,087	2020	839	839	4.3%	4.3%
2002 to 2030	19,146	19,146	2030	963	963	4.3%	4.3%

(Low/High under "Year" columns: Fuel Displaced in Year Indicated)

2001 Dollars Per Gallon of Conventional Fuel Displaced

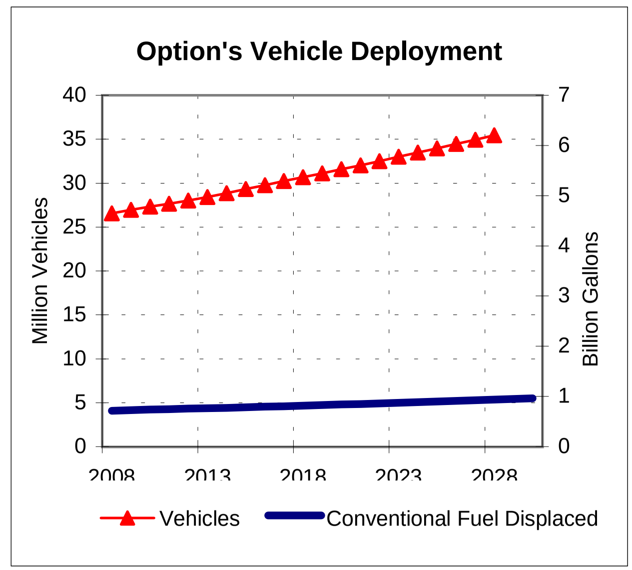
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.00	$0.00	($0.51)	($0.51)	($0.51)	($0.51)
2020	$0.00	$0.00	($0.51)	($0.51)	($0.51)	($0.51)
2030	$0.00	$0.00	($0.51)	($0.51)	($0.51)	($0.51)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.64
Low Fuel Price Estimate ($/gallon)	$1.64
For This Option:	
Vehicle Fuel Economy (mi/gallon)	20.9
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.62
Low Fuel Price ($/Gallon)	$1.62
Vehicle Life (years)	15
Discount Rate (%)	5%



GGE = Gallons Gasoline Equivalents

Table 2G-3

Summary of Analysis Results
Option 2G: Use of Ethanol in California Reformulated Gasoline

Fuel Price: $1.81

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($880)	($880)	($779)	($779)	($1,658)	($1,658)
2002 to 2020	($3,268)	($3,268)	($2,893)	($2,893)	($6,162)	($6,162)
2002 to 2030	($4,944)	($4,944)	($4,377)	($4,377)	($9,321)	($9,321)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($425)	($425)	($376)	($376)	($800)	($800)
2020	($487)	($487)	($431)	($431)	($917)	($917)
2030	($559)	($559)	($494)	($494)	($1,053)	($1,053)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	2,180	2,180	2010	737	737	4.3%	4.3%
2002 to 2020	10,087	10,087	2020	839	839	4.3%	4.3%
2002 to 2030	19,146	19,146	2030	963	963	4.3%	4.3%

2001 Dollars Per Gallon of Conventional Fuel Displaced

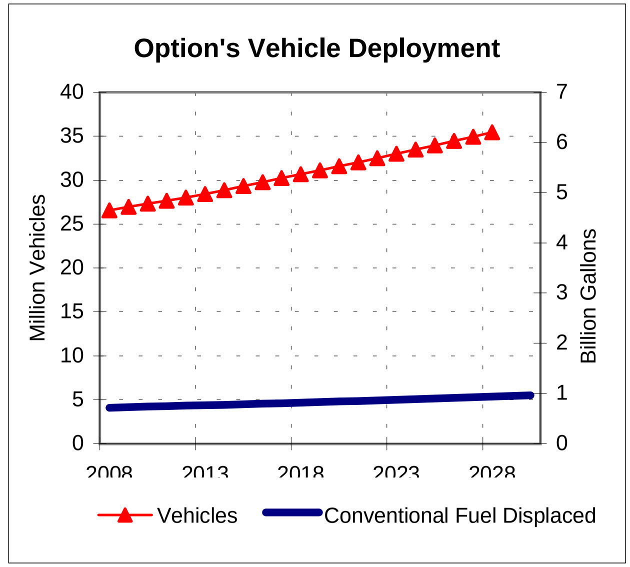
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.58)	($0.58)	($0.51)	($0.51)	($1.09)	($1.09)
2020	($0.58)	($0.58)	($0.51)	($0.51)	($1.09)	($1.09)
2030	($0.58)	($0.58)	($0.51)	($0.51)	($1.09)	($1.09)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	21.2
High Fuel Price Estimate ($/gallon)	$1.81
Low Fuel Price Estimate ($/gallon)	$1.81
For This Option:	
Vehicle Fuel Economy (mi/gallon)	20.9
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.81
Low Fuel Price ($/Gallon)	$1.81
Vehicle Life (years)	15
Discount Rate (%)	5%



GGE = Gallons Gasoline Equivalents

Staff Paper on Option 2H
LNG and Advanced NG Engines for Medium- and Heavy-Duty Vehicles

Description

This option explores a regulatory or incentive-based strategy intended to increase the use of natural gas in medium- and heavy-duty on road vehicles.

Background

On-road medium- and heavy-duty vehicles are defined as vehicles with gross vehicle weight greater than 8,500 pounds. Expanded use of alternative fuels in medium-duty and heavy-duty trucks using more efficient, advanced natural gas engine technologies can reduce projected diesel fuel use from this sector. This option explores the use of compressed natural gas (CNG) in medium-duty vehicles and liquefied natural gas (LNG) or CNG in heavy-duty vehicles. Each would replace a vehicle normally fueled with diesel.

Medium-duty and heavy-duty trucks move much of the nation's goods and are considered vital to the economy. Due to the typical driving cycle of medium-duty trucks, usually intra-city or regional service, these vehicles can effectively use CNG when centrally refueled. Heavy-duty vehicles can also effectively use CNG in driving cycles similar to those for medium-duty vehicles in short range applications. For intra- and interstate delivery routes, heavy-duty vehicles dominate transport service and require the greater range capability offered by LNG.

Natural gas medium- and heavy-duty vehicles are an attractive environmental option to diesel fueled vehicles because they emit fewer criteria pollutants and toxic components. The limited availability of refueling facilities and typically higher vehicle purchase prices, however, have affected the sale of this fuel option in these applications.

Staff limited this option to dedicated CNG and LNG vehicles in order to evaluate maximum diesel displacement. Dual-fueled and bi-fueled vehicles would cost more to purchase as they have both a diesel and a CNG or LNG fueling system. Since they would use diesel, they would displace less diesel fuel. The trend, however, is for the market to purchase more natural gas vehicles but use less natural gas per vehicle, probably due to the use of dual-fueled and bi-fueled vehicles.[1]

Status

Some medium- and heavy-duty trucks already use natural gas instead of diesel fuel. For some, a small amount of pilot diesel fuel is used to initiate the combustion. Efforts are under way to limit the amount of pilot diesel fuel needed, and to minimize emissions. Today's economics tend to favor diesel fuel and opportunities to use natural gas are limited. Municipal vehicles, including trash haul applications, street sweepers and utility trucks using natural gas have all been demonstrated. Heavy-duty applications of natural gas include transport of goods by major store brands such as Raley's and Von's using CNG, and line-haul trucking such as Harris Ranch with LNG.

Natural gas and natural gas vehicle stake holders have joined forces to establish two working groups to advance the state of natural gas heavy-duty vehicles. One is working to improve the vehicles, and the other is working to improve fueling infrastructure.

The U. S. Department of Energy and other stakeholders are working jointly to improve the performance of medium-duty and heavy-duty natural gas vehicle technologies.[2] Their near-term objective is to deploy one Class 3-6 by 2004 and one Class 7-8 vehicle by 2007, both of which will be designed to be commercially viable and meet year 2007 emissions targets while significantly advancing the performance capability of natural gas in these applications. Funding needs are $5 million in 2003 and 2004, decreasing annually to $1.25 million in 2007. They do not specifically identify efficiency targets. If funded, they expect that vehicles developed under this program will lead to commercial offerings that will achieve limited market scope with current incentive programs aimed at reducing emissions or displacing petroleum fuels.

Many of the same stakeholders are also involved in improving the refueling infrastructure in an effort to build the market for natural gas vehicles.[3] This effort focuses upon improved gas compression methods and component integration for compressed natural gas (CNG) and lowering the cost of liquefied natural gas (LNG) production by developing small-scale LNG production technology and lower cost equipment. Ensuring safety and reliability are important aspects of this work.

The California Natural Gas Partnership, established in the spring of 2002 by the South Coast Air Quality Management District, has established aggressive vehicle deployment targets and fuel use as shown in Table 2H-1.[4] These goals are much greater than the number of vehicles used in this analysis.

Table 2H-1. California NGV Partnership Goals

	2005	**2007**	**2012**
New Light-Duty NGVs	33,000	90,000	500,000
New Heavy-Duty NGVs	10,000	25,000	100,000
Annual CNG Use (gge, million)	83	220	1,076
Annual LNG Use (gge, million)	95	240	955

Assumptions

Diesel demand reductions in 2010, 2020 and 2030 from on-road heavy-duty vehicles are estimated based on projected sales of natural gas heavy-duty vehicles, associated improvements in advanced natural gas engine fuel economy, existing and projected vehicle populations, infrastructure costs and other assumptions.

Staff determined weighted averages of the year 2000 vehicle fuel economies for the existing relevant diesel vehicle classes using several sources. In the analysis, staff began with base case vehicles that achieve 12.7 miles per gallon of diesel in Class 3-6 vehicles and 6.5 miles per gallon of diesel in Class 7-8 vehicles.

Fuel economies and vehicle miles traveled are weighted across vehicle classes.

All new natural gas vehicles sold by 2020 are fully competitive with conventional diesel vehicles on performance, reliability and durability bases, and meet prevailing emission standards. Compression ignition-based LNG vehicles meet prevailing fuel economy performance of diesel engines. Spark ignition-based CNG engine platforms meet 95 percent of prevailing diesel engine fuel economy performance, due to heavier on-board fuel tanks and throttling losses associated with spark ignition.

All new vehicles sold replace diesel-fueled vehicles because diesels dominate the vehicle population segment considered.

Variable penetration rates in all vehicle classes with higher rates in some classes and time periods than others.[5]

Certain costs are associated with achieving the assumed penetration rates and estimated petroleum displacements for NGVs. These include incremental capital cost, incremental fuel cost, incremental operation and maintenance costs and an incremental infrastructure cost. These costs vary among vehicle classes.

Staff assumed that R&D successfully reduces incremental capital costs of medium-duty CNG vehicles from a high of $11,000 in 1997 to $9,500 to $2,000 by 2030. Likewise, staff assumed that R&D successfully reduces incremental capital cost of CNG Class 7-8 heavy-duty vehicles from a high of $45,000 in 1997 to $10,500 by 2030. Similarly, the incremental capital cost of LNG Class 7-8 heavy-duty vehicles decreases from $28,767 in 1997 to $17,000 to $4,700 by 2030. All are expressed in 2001 dollars.

Staff developed compressed natural gas fuel costs using the same approach described in Option 2D (CNG for Light-Duty Vehicles) except results are expressed here in diesel fuel equivalent values rather than gasoline fuel equivalent values. First, we used the Energy Commission's commercial end-use price forecast from 2002 to 2020, adjusted with plus and minus one standard deviation (scaled to gasoline price variability) to determine a range of natural gas commodity prices, assuming commercial operation of public refueling facilities. These were $0.327 to $0.587 per therm of gas. Next, we added expected capital recovery for station upgrades (estimated from current natural gas utility tariffs for CNG at utility-owned public refueling stations, with scaling to account for larger volume throughput) and added expected electricity and maintenance charges, based upon existing natural gas utility tariffs. This added another $0.200 to $0.270 per therm of gas. Next, we added state and federal fuel excise taxes, sales tax and natural gas regulatory fees to arrive at final CNG price range of $0.97 to $1.38 per therm (equivalent to $1.45 to $2.22 per gallon of diesel on an energy content basis, expressed "DGE").

Results

Class 3-6 Medium-Duty CNG Vehicles. Tables 2H-2 through 2H-4 display the summary results for Class 3-6 medium-duty CNG vehicles. Negative values in the table are costs either to the consumer or to the government and are shown with parentheses. These vehicles are predicted to cost more to operate than Class 3-6 diesel vehicles. They are expected to cost from $2,000 to $9,500 more than their diesel counterparts and the fuel is expected to be more expensive except at the low price point.

Table 2H-3 shows results for the midpoint diesel price of $1.65 per gallon and the midpoint CNG price. Between 2008 and 2010, the spreadsheet results indicate that owners would spend an extra $1.1 to $2.9 million to operate these vehicles rather than comparable diesel vehicles, on a net present value basis and expressed in year 2001 dollars. Correspondingly, government would lose $0.9 million in revenue due to different tax rates for CNG versus diesel, for overall increased costs of $2.0 to $3.8 million. As shown in the table, these values grow in later years.

When the costs are evaluated for individual years, similar results are seen. In 2010, consumers would lose $0.7 to $1.8 million while government would lose $0.7 million. Net losses would total $1.4 to $2.4 million. Again, costs increase in later years.

On the other hand, Class 3-6 medium-duty CNG vehicles would displace 0.1 percent of the on road diesel forecasted to be used in 2010, 0.3 percent by 2020 and 0.4 percent by 2030. Displacing each gallon of diesel using these vehicles would cost $0.55 to $.96 in 2010, $0.52 to $0.81 in 2020 and $0.51 to $0.76 in 2030. These dollars are in year expended, and are not on a net present value basis.

Class 7-8 Heavy-Duty CNG Vehicles. Tables 2H-5 through 2H-7 display the summary results for Class 7-8 heavy-duty CNG vehicles. Negative values in the table are costs either to the consumer or to the government and are shown with parentheses. These vehicles are expected to cost from $10,500 to $20,000 more than their diesel counterparts and the fuel is expected to be more expensive, except at the low price point.

Table 2H-6 shows results for the midpoint diesel price of $1.65 per gallon and the midpoint CNG price. Between 2008 and 2010, the spreadsheet results indicate that owners would spend an extra $11 to $13 million to operate these vehicles rather than comparable diesel vehicles, on a net present value basis and expressed in year 2001 dollars. Correspondingly, government would lose $6 million in revenue due to different tax rates for CNG versus diesel, for overall increased costs of $16 to $19 million. As shown in the table, these values grow in later years.

When the costs are evaluated for individual years, similar results are seen. In 2010, consumers would lose $7.2 to $8.8 million while government would lose $3.9 million. Net losses would total $11.2 to $12.8 million. Again, costs would grow in later years.

On the other hand, Class 7-8 heavy-duty CNG vehicles would displace 0.5 percent of the on road diesel forecasted to be used in 2010, 2.1 percent by 2020 and 2.4 percent by 2030. Displacing each gallon of diesel using these vehicles would cost $0.69 to $.79 in 2010, $0.66 to $0.73 in

2020 and $0.65 to $0.71 in 2030. These dollars are in year expended, and are not on a net present value basis.

Class 7-8 Heavy-Duty LNG Vehicles. Tables 2H-8 through 2H-10 display the summary results for class 7-8 heavy-duty LNG vehicles. Negative values in the table are costs either to the consumer or to the government and are shown with parentheses. These vehicles are predicted to cost less to operate than Class 7-8 diesel vehicles for most of the range of costs. They are, however, expected to cost from $4,700 to $17,000 more than their diesel counterparts. Contrary to CNG, their fuel is expected to be less expensive than diesel. This is not sufficient, however, to overcome the higher end of the incremental capital cost range used in this analysis.

Table 2H-9 shows results for the midpoint diesel price of $1.65 per gallon and the midpoint CNG price. Between 2008 and 2010, the results indicate that owners would save $1 to $4 million to operate these vehicles rather than comparable diesel vehicles (on a net present value basis and expressed in year 2001 dollars). Correspondingly, government would lose $7 million in revenue due to different tax rates for LNG versus diesel, for overall increased costs of $3 to $6 million. As shown in the table, these values grow in later years.

When the costs are evaluated for individual years, similar results are seen. In 2010, consumers would save $0.9 to $3.0 million while government would lose $4.8 million. Net losses would total $1.8 to $3.8 million. Again, values grow in later years.

On the other hand, Class 7-8 heavy-duty LNG vehicles would displace 0.5 percent of the on road diesel forecasted to be used in 2010, 2.1 percent by 2020 and 2.4 percent by 2030. Displacing each gallon of diesel using these vehicles would cost $0.11 to $0.24 in 2010; $0.10 to $0.19 in 2020 and $0.09 to $0.17 in 2030. These dollars are in year expended, and are not on a net present value basis.

Class 7-8 heavy-duty vehicles appear more attractive for LNG than for CNG from both cost and vehicle operating range perspectives.

Key Drivers and Uncertainties

- It is uncertain whether the fuel economy of natural gas vehicles can approach that of diesel fueled vehicles.

- It is uncertain that the efficiency of a natural gas engine could match that of a corresponding diesel engine.

- It is uncertain if the percentage of vehicles in each class will remain the same.

- It is uncertain whether vehicle miles traveled are the same for diesel and natural gas vehicles (affects demand reduction and incremental operating costs).

- It is uncertain whether a more rapid fleet turnover in the years 2015-2030 as vehicle fleet ages and replacement is justified by lower operating cost from more fuel-efficient vehicles.

[1] Natural Gas Fuels, November 2002, page 8.

[2] Next-Generation Natural Gas Vehicle Program, Vehicle Working Group Workshop and Meeting, October, 2001.

[3] Natural Gas Vehicle Infrastructure Working Group and Vehicle Working Group, Summary of Recommendations to Overcome Natural Gas Vehicle Infrastructure Technology Obstacles, September 2001.

[4] Natural Gas Fuels, November 2002, page 7.

[5] As used in this analysis, vehicle penetration rate means a percentage of new vehicles entering the existing fleet population. For this scenario, 100 percent of new vehicles sold meet the assumed fuel economy targets used in the analysis. It is estimated that new vehicle sales are fewer than 10 percent of the existing population in any given year. The penetration rate is varied to reflect rapid turnover of the vehicle population. A higher penetration rate is assumed to occur in the years 2015-2030 from aging and the availability of more fuel-efficient vehicles. A composite vehicle class distribution is used in estimating the vehicle penetrations.

Table 2H-2

Summary of Analysis Results

Option 2H: Advanced NG Engines for Medium- and Heavy-Duty Vehicles

Case: Class 3-6 Medium-Duty CNG Vehicles; Fuel Price: $1.48

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($2.1)	($0.4)	($0.9)	($0.9)	($3.0)	($1.3)
2002 to 2020	($19.5)	($3.1)	($12.1)	($12.1)	($31.6)	($15.2)
2002 to 2030	($36.3)	($5.5)	($26.5)	($26.5)	($62.8)	($31.9)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($1.2)	($0.2)	($0.7)	($0.7)	($1.9)	($0.9)
2020	($4.7)	($0.7)	($3.6)	($3.6)	($8.3)	($4.3)
2030	($5.2)	($0.7)	($4.7)	($4.7)	($9.9)	($5.4)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
			Fuel Displaced in Year Indicated				
2002 to 2010	5.1	5.1	2010	2.5	2.5	0.1%	0.1%
2002 to 2020	93	93	2020	13.8	13.8	0.3%	0.3%
2002 to 2030	268	268	2030	18.3	18.3	0.4%	0.4%

2001 Dollars Per Gallon of Conventional Fuel Displaced

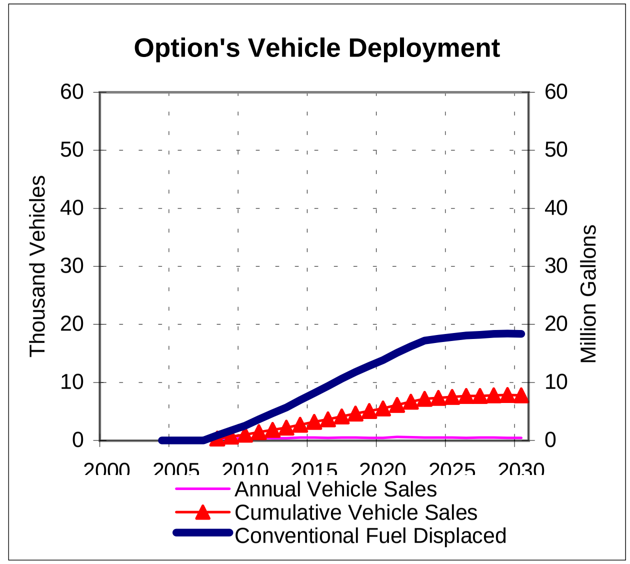
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.49)	($0.08)	($0.26)	($0.26)	($0.75)	($0.34)
2020	($0.34)	($0.05)	($0.26)	($0.26)	($0.60)	($0.31)
2030	($0.28)	($0.04)	($0.26)	($0.26)	($0.54)	($0.30)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	12.5
High Fuel Price Estimate ($/gallon)	$1.48
Low Fuel Price Estimate ($/gallon)	$1.48
For This Option:	
Vehicle Fuel Economy (mi/DGE)	12.5
High Incremental Cost ($ per vehicle)	$9,500
Low Incremental Cost ($ per vehicle)	$2,000
High Fuel Price ($/DGE)	$1.453
Low Fuel Price ($/DGE)	$1.453
Vehicle Life (years)	16
Discount Rate (%)	5%



DGE = Diesel Gallon Equivalents

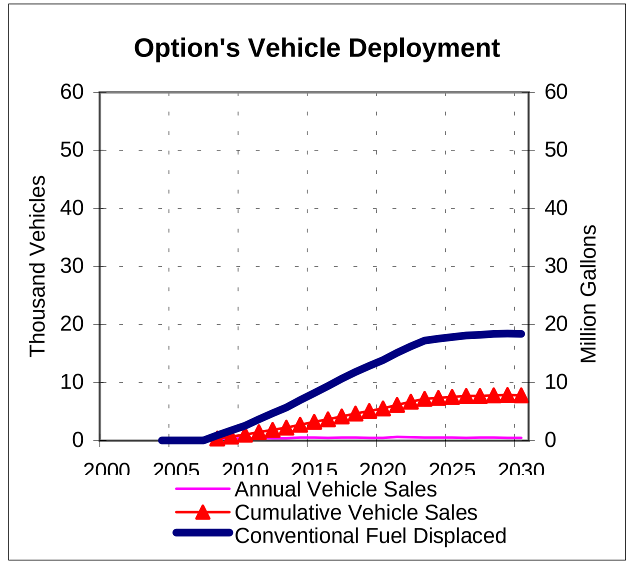
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($2.9)	($1.1)	($0.9)	($0.9)	($3.8)	($2.0)
2002 to 2020	($29.5)	($13.1)	($12.1)	($12.1)	($41.6)	($25.2)
2002 to 2030	($58.2)	($27.4)	($26.5)	($26.5)	($84.7)	($53.8)

Fuel Economy (mi/gallon)	12.5
High Fuel Price Estimate ($/gallon)	$1.65
Low Fuel Price Estimate ($/gallon)	$1.65

Vehicle Fuel Economy (mi/DGE)	12.5
High Incremental Cost ($ per vehicle)	$9,500
Low Incremental Cost ($ per vehicle)	$2,000
High Fuel Price ($/DGE)	$1.836
Low Fuel Price ($/DGE)	$1.836
Vehicle Life (years)	16
Discount Rate (%)	5%

2010	($1.8)	($0.7)	($0.7)	($0.7)	($2.4)	($1.4)
2020	($7.7)	($3.6)	($3.6)	($3.6)	($11.2)	($7.2)
2030	($9.1)	($4.6)	($4.7)	($4.7)	($13.9)	($9.3)

	Low	High	Year	Low	High	Low %	High %
2002 to 2010	5.1	5.1	2010	2.5	2.5	0.1%	0.1%
2002 to 2020	93	93	2020	13.8	13.8	0.3%	0.3%
2002 to 2030	268	268	2030	18.3	18.3	0.4%	0.4%



	[1]	[2]	Low	High	[1]	[2]
2010	($0.70)	($0.29)	($0.26)	($0.26)	($0.96)	($0.55)
2020	($0.55)	($0.26)	($0.26)	($0.26)	($0.81)	($0.52)
2030	($0.50)	($0.25)	($0.26)	($0.26)	($0.76)	($0.51)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

DGE = Diesel Gallon Equivalents

Table 2H-4

Summary of Analysis Results

Option 2H: Advanced NG Engines for Medium- and Heavy-Duty Vehicles

Case: Class 3-6 Medium-Duty CNG Vehicles; Fuel Price: $1.82

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($3.6)	($1.9)	($0.9)	($0.9)	($4.5)	($2.8)
2002 to 2020	($39.5)	($23.1)	($12.1)	($12.1)	($51.6)	($35.2)
2002 to 2030	($80.1)	($49.3)	($26.5)	($26.5)	($106.6)	($75.8)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($2.3)	($1.3)	($0.7)	($0.7)	($3.0)	($1.9)
2020	($10.6)	($6.6)	($3.6)	($3.6)	($14.2)	($10.2)
2030	($13.0)	($8.5)	($4.7)	($4.7)	($17.8)	($13.3)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	5.1	5.1	2010	2.5	2.5	0.1%	0.1%
2002 to 2020	93	93	2020	13.8	13.8	0.3%	0.3%
2002 to 2030	268	268	2030	18.3	18.3	0.4%	0.4%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.91)	($0.51)	($0.26)	($0.26)	($1.17)	($0.77)
2020	($0.77)	($0.48)	($0.26)	($0.26)	($1.02)	($0.73)
2030	($0.71)	($0.46)	($0.26)	($0.26)	($0.97)	($0.72)

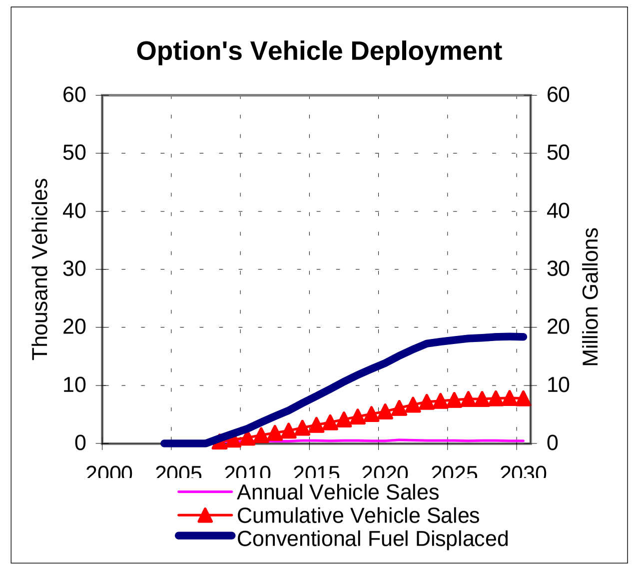
[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	12.5
High Fuel Price Estimate ($/gallon)	$1.82
Low Fuel Price Estimate ($/gallon)	$1.82

For This Option:	
Vehicle Fuel Economy (mi/DGE)	12.5
High Incremental Cost ($ per vehicle)	$9,500
Low Incremental Cost ($ per vehicle)	$2,000
High Fuel Price ($/DGE)	$2.219
Low Fuel Price ($/DGE)	$2.219
Vehicle Life (years)	16
Discount Rate (%)	5%



DGE = Diesel Gallon Equivalents

Table 2H-5

Summary of Analysis Results

Option 2H: Advanced NG Engines for Medium- and Heavy-Duty Vehicles

Case: Class 7-8 Heavy-Duty CNG Vehicles; Fuel Price: $1.48

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($8)	($5)	($6)	($6)	($13)	($11)
2002 to 2020	($82)	($56)	($73)	($73)	($155)	($129)
2002 to 2030	($162)	($115)	($160)	($160)	($323)	($275)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($4.9)	($3.3)	($3.9)	($3.9)	($8.8)	($7.2)
2020	($21.4)	($15.2)	($21.6)	($21.6)	($43.0)	($36.8)
2030	($25.7)	($18.8)	($28.6)	($28.6)	($54.3)	($47.4)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	32.7	32.7	2010	16.2	16.2	0.5%	0.5%
2002 to 2020	593	593	2020	88.5	88.5	2.1%	2.1%
2002 to 2030	1,713	1,713	2030	117.2	117.2	2.4%	2.4%

(Low, High, Low % and High % under "Fuel Displaced in Year Indicated".)

2001 Dollars Per Gallon of Conventional Fuel Displaced

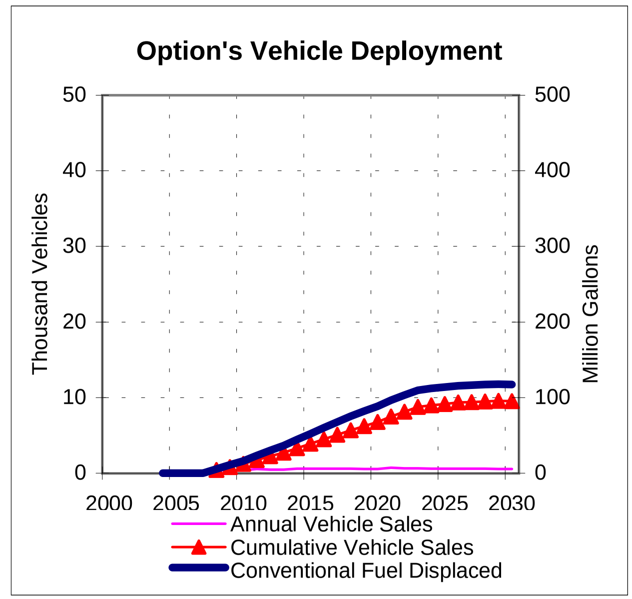
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.30)	($0.20)	($0.24)	($0.24)	($0.55)	($0.45)
2020	($0.24)	($0.17)	($0.24)	($0.24)	($0.49)	($0.42)
2030	($0.22)	($0.16)	($0.24)	($0.24)	($0.46)	($0.40)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.48
Low Fuel Price Estimate ($/gallon)	$1.48
For This Option:	
Vehicle Fuel Economy (mi/DGE)	6.0
High Incremental Cost ($ per vehicle)	$20,000
Low Incremental Cost ($ per vehicle)	$10,500
High Fuel Price ($/DGE)	$1.453
Low Fuel Price ($/DGE)	$1.453
Vehicle Life (years)	16
Discount Rate (%)	5%



DGE = Diesel Gallon Equivalents

Table 2H-6

Summary of Analysis Results

Option 2H: Advanced NG Engines for Medium- and Heavy-Duty Vehicles

Case: Class 7-8 Heavy-Duty CNG Vehicles; Fuel Price: $1.65

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($13)	($11)	($6)	($6)	($19)	($16)
2002 to 2020	($155)	($130)	($73)	($73)	($228)	($203)
2002 to 2030	($323)	($276)	($160)	($160)	($483)	($436)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($8.8)	($7.2)	($3.9)	($3.9)	($12.8)	($11.2)
2020	($43.1)	($36.9)	($21.6)	($21.6)	($64.6)	($58.4)
2030	($54.5)	($47.5)	($28.6)	($28.6)	($83.1)	($76.1)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period			Fuel Displaced in Year Indicated				
	Low	High	Year	Low	High	Low %	High %
2002 to 2010	32.7	32.7	2010	16.2	16.2	0.5%	0.5%
2002 to 2020	593	593	2020	88.5	88.5	2.1%	2.1%
2002 to 2030	1,713	1,713	2030	117.2	117.2	2.4%	2.4%

2001 Dollars Per Gallon of Conventional Fuel Displaced

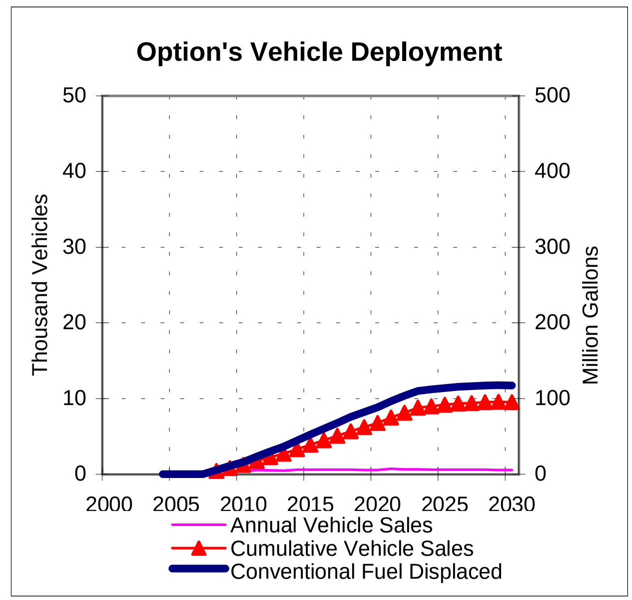
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.55)	($0.45)	($0.24)	($0.24)	($0.79)	($0.69)
2020	($0.49)	($0.42)	($0.24)	($0.24)	($0.73)	($0.66)
2030	($0.46)	($0.40)	($0.24)	($0.24)	($0.71)	($0.65)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.65
Low Fuel Price Estimate ($/gallon)	$1.65
For This Option:	
Vehicle Fuel Economy (mi/DGE)	6.0
High Incremental Cost ($ per vehicle)	$20,000
Low Incremental Cost ($ per vehicle)	$10,500
High Fuel Price ($/DGE)	$1.836
Low Fuel Price ($/DGE)	$1.836
Vehicle Life (years)	16
Discount Rate (%)	5%



DGE = Diesel Gallon Equivalents

Table 2H-7

Summary of Analysis Results

Option 2H: Advanced NG Engines for Medium- and Heavy-Duty Vehicles

Case: Class 7-8 Heavy-Duty CNG Vehicles; Fuel Price: $1.82

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($19)	($16)	($6)	($6)	($25)	($22)
2002 to 2020	($229)	($203)	($73)	($73)	($302)	($277)
2002 to 2030	($484)	($436)	($160)	($160)	($644)	($597)

Single Year Savings in Millions of 2001 Dollars

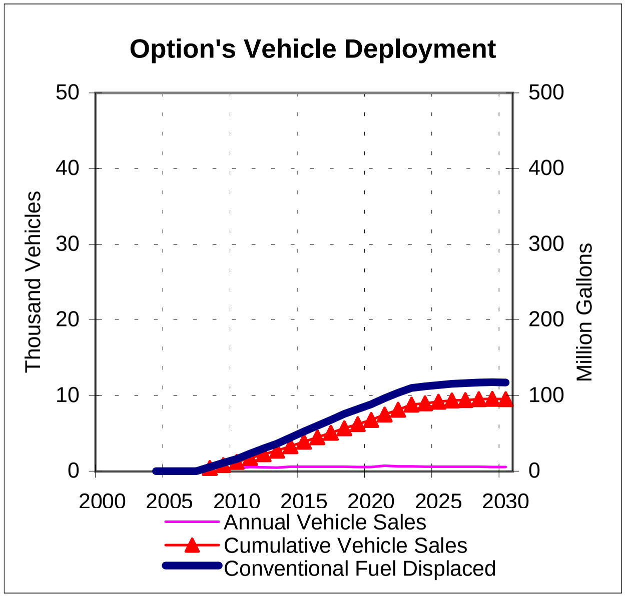
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($12.8)	($11.2)	($3.9)	($3.9)	($16.7)	($15.1)
2020	($64.7)	($58.5)	($21.6)	($21.6)	($86.3)	($80.1)
2030	($83.2)	($76.2)	($28.6)	($28.6)	($111.8)	($104.8)

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.82
Low Fuel Price Estimate ($/gallon)	$1.82
For This Option:	
Vehicle Fuel Economy (mi/DGE)	6.0
High Incremental Cost ($ per vehicle)	$20,000
Low Incremental Cost ($ per vehicle)	$10,500
High Fuel Price ($/DGE)	$2.219
Low Fuel Price ($/DGE)	$2.219
Vehicle Life (years)	16
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated Low	High	Low %	High %
2002 to 2010	32.7	32.7	2010	16.2	16.2	0.5%	0.5%
2002 to 2020	593	593	2020	88.5	88.5	2.1%	2.1%
2002 to 2030	1,713	1,713	2030	117.2	117.2	2.4%	2.4%



DGE = Diesel Gallon Equivalents

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.79)	($0.69)	($0.24)	($0.24)	($1.04)	($0.94)
2020	($0.73)	($0.66)	($0.24)	($0.24)	($0.98)	($0.91)
2030	($0.71)	($0.65)	($0.24)	($0.24)	($0.95)	($0.89)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2H-8

Summary of Analysis Results

Option 2H: Advanced NG Engines for Medium- and Heavy-Duty Vehicles

Case: Class 7- 8 Heavy-Duty LNG Vehicles; Fuel Price: $1.48

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$3	$7	($7)	($7)	($3)	($0)
2002 to 2020	$60	$93	($88)	($88)	($29)	$4
2002 to 2030	$145	$207	($193)	($193)	($49)	$13

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$2.8	$4.9	($4.8)	($4.8)	($1.9)	$0.1
2020	$19.9	$27.9	($26.0)	($26.0)	($6.1)	$1.9
2030	$28.6	$37.6	($34.5)	($34.5)	($5.9)	$3.1

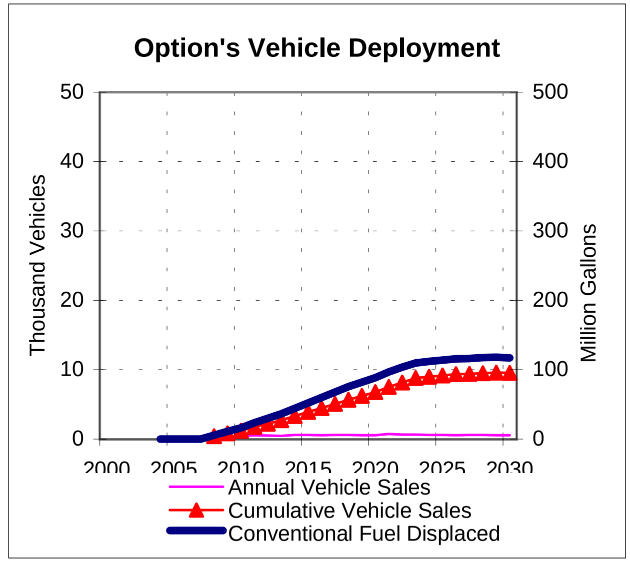
MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.48
Low Fuel Price Estimate ($/gallon)	$1.48
For This Option:	
Vehicle Fuel Economy (mi/DGE)	6.5
High Incremental Cost ($ per vehicle)	$17,000
Low Incremental Cost ($ per vehicle)	$4,700
High Fuel Price ($/DGE)	$1.13
Low Fuel Price ($/DGE)	$1.13
Vehicle Life (years)	16
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Low	High	Low %	High %
2002 to 2010	32.7	32.7	2010	16.2	16.2	0.5%	0.5%
2002 to 2020	593	593	2020	88.5	88.5	2.1%	2.1%
2002 to 2030	1,713	1,713	2030	117.2	117.2	2.4%	2.4%

(Fuel Displaced in Year Indicated: Year, Low, High, Low %, High %)



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.17	$0.30	($0.29)	($0.29)	($0.12)	$0.01
2020	$0.22	$0.32	($0.29)	($0.29)	($0.07)	$0.02
2030	$0.24	$0.32	($0.29)	($0.29)	($0.05)	$0.03

DGE = Diesel Gallon Equivalents

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2H-9

Summary of Analysis Results

Option 2H: Advanced NG Engines for Medium- and Heavy-Duty Vehicles

Case: Class 7- 8 Heavy-Duty LNG Vehicles; Fuel Price: $1.65

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$1	$4	($7)	($7)	($6)	($3)
2002 to 2020	$25	$57	($88)	($88)	($64)	($31)
2002 to 2030	$68	$130	($193)	($193)	($126)	($64)

Single Year Savings in Millions of 2001 Dollars

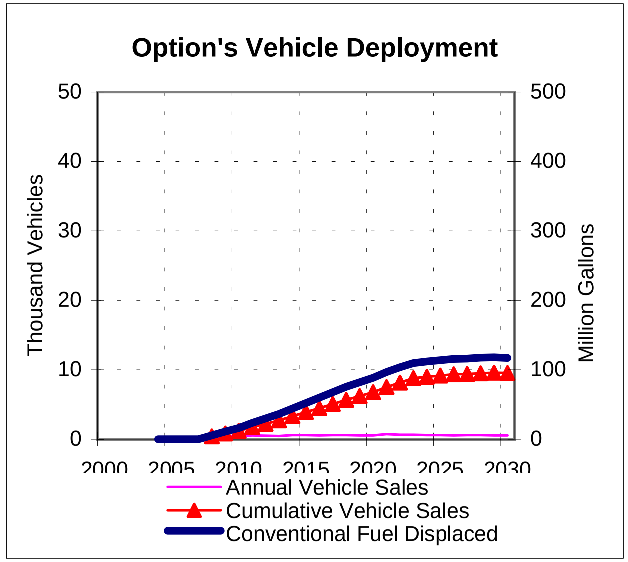
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$0.9	$3.0	($4.8)	($4.8)	($3.8)	($1.8)
2020	$9.5	$17.6	($26.0)	($26.0)	($16.5)	($8.5)
2030	$14.9	$23.9	($34.5)	($34.5)	($19.7)	($10.6)

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.65
Low Fuel Price Estimate ($/gallon)	$1.65
For This Option:	
Vehicle Fuel Economy (mi/DGE)	6.5
High Incremental Cost ($ per vehicle)	$17,000
Low Incremental Cost ($ per vehicle)	$4,700
High Fuel Price ($/DGE)	$1.42
Low Fuel Price ($/DGE)	$1.42
Vehicle Life (years)	16
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	32.7	32.7	2010	16.2	16.2	0.5%	0.5%
2002 to 2020	593	593	2020	88.5	88.5	2.1%	2.1%
2002 to 2030	1,713	1,713	2030	117.2	117.2	2.4%	2.4%



DGE = Diesel Gallon Equivalents

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.06	$0.18	($0.29)	($0.29)	($0.24)	($0.11)
2020	$0.11	$0.20	($0.29)	($0.29)	($0.19)	($0.10)
2030	$0.13	$0.20	($0.29)	($0.29)	($0.17)	($0.09)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2H-10

Summary of Analysis Results

Option 2H: Advanced NG Engines for Medium- and Heavy-Duty Vehicles

Case: Class 7- 8 Heavy-Duty LNG Vehicles; Fuel Price: $1.82

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($2.1)	$1.3	($7)	($7)	($9)	($5)
2002 to 2020	($10.5)	$22.3	($88)	($88)	($99)	($66)
2002 to 2030	($9.1)	$52.6	($193)	($193)	($202)	($141)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($1.0)	$1.1	($4.8)	($4.8)	($5.7)	($3.7)
2020	($0.8)	$7.2	($26.0)	($26.0)	($26.9)	($18.8)
2030	$1.1	$10.2	($34.5)	($34.5)	($33.4)	($24.4)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	32.7	32.7	2010	16.2	16.2	0.5%	0.5%
2002 to 2020	593	593	2020	88.5	88.5	2.1%	2.1%
2002 to 2030	1,713	1,713	2030	117.2	117.2	2.4%	2.4%

2001 Dollars Per Gallon of Conventional Fuel Displaced

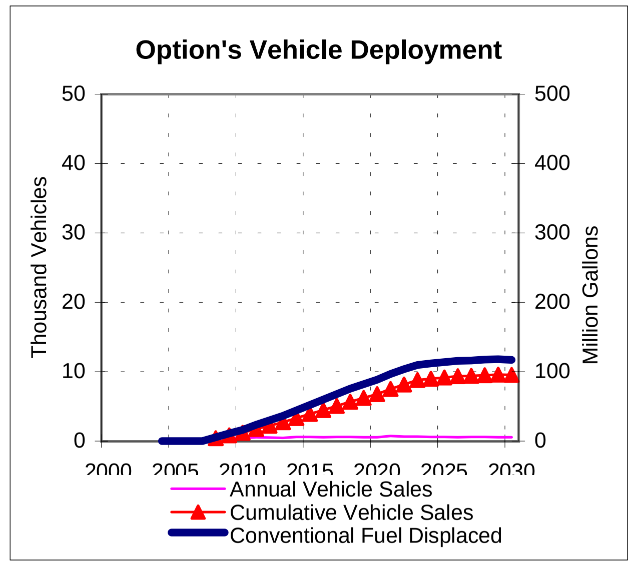
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.06)	$0.07	($0.29)	($0.29)	($0.35)	($0.23)
2020	($0.01)	$0.08	($0.29)	($0.29)	($0.30)	($0.21)
2030	$0.01	$0.09	($0.29)	($0.29)	($0.28)	($0.21)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.82
Low Fuel Price Estimate ($/gallon)	$1.82
For This Option:	
Vehicle Fuel Economy (mi/DGE)	6.5
High Incremental Cost ($ per vehicle)	$17,000
Low Incremental Cost ($ per vehicle)	$4,700
High Fuel Price ($/DGE)	$1.70
Low Fuel Price ($/DGE)	$1.70
Vehicle Life (years)	16
Discount Rate (%)	5%



DGE = Diesel Gallon Equivalents

Staff Paper on Option 2I
Fischer-Tropsch Diesel

Description

This option considers the adoption of policy (fiscal or regulatory) that would result in greater use of Fischer-Tropsch diesel (FT diesel). Such policy could involve a reduction in fuel excise tax for diesel fuel when blended with a percentage of FT diesel or a diesel fuel specification for cetane number and aromatic content that would encourage the use of FT diesel over other refinery options.

Background

FT diesel is made by using a catalyst to convert a feed gas, such as natural gas, into a synthetic diesel fuel. Recent advances in catalyst technology promise competitively priced FT diesel within the range of possible economic conditions found in the current California diesel fuel market.

FT diesel can be used directly in some existing stationary engines, and can be made compatible with light and heavy diesel engines for use in vehicles. Testing in unmodified diesel engines has shown reductions in hydrocarbons, carbon monoxide, NO_x, and particulate matter compared to California diesel fuel.[1]

Large quantities of remote natural gas, located too far from urban centers to be piped and used as a local fuel, are very attractive and economic sources of feed gas for producing FT diesel. Another potentially attractive source of feed gas is gas produced as a byproduct of oil recovery. FT diesel represents a beneficial supply alternative to conventional diesel fuel, or a blending component to produce greater volumes of low aromatic, lower sulfur diesel.

The nature of the remote location of feed stocks for FT diesel may be an issue, as many are the same geographical location(s) as imported crude oil. Importing large quantities of FT diesel may reduce the burden on petroleum diesel supplies, but they may face the same geographic and political issues as crude oil or refined products imported from those regions.

Status

Nearly every major oil company has announced plans to produce FT diesel. Limited imports of FT diesel over the period from 1993 through 1998 were used by several refiners to blend FT diesel with heavier, less desirable crude oil to make greater volumes of California's unique low-aromatic CARB diesel fuel.

The use of FT diesel is being driven by a need to produce a diesel fuel with lower aromatic content and higher cetane level. Regulations adopted by the California Air Resources Board (CARB) require that diesel fuel sold in-state be limited to 10 percent by weight total aromatics (CARB diesel) or must meet an alternative formulation that produces equivalent emission benefits. Currently, all diesel fuel produced in California for in-state sale meets optional specifications for total aromatic content and cetane number in lieu of the uniform diesel aromatic content of 10 percent. With a sufficient price differential between CARB diesel and diesel produced for the rest of the U.S. (i.e., EPA diesel), FT diesel can be the most economical option to blend with EPA diesel to produce a CARB alternative formulation diesel.

According to the U.S. Environmental Protection Agency, a diesel fuel formulated with FT diesel derived from natural gas would normally satisfy federal requirements for registration as a baseline diesel fuel.[2] Currently, there is no federal limitation on the amount of FT diesel that can be combined with petroleum diesel under the registration constraints.

Today, the major barrier to widespread use of FT diesel is its cost. At today's diesel prices, FT diesel costs about 10 cents more per gallon to produce, and retail prices are expected to be 15 to 25 cents per gallon higher than conventional, petroleum-derived diesel. New federal and state fuel specifications will likely increase the cost of conventional diesel, reducing the incremental cost of FT diesel to 5 to 10 cents per gallon by 2006.

The potential worldwide availability of FT diesel over time has been projected from industry sources. These values are shown in Table 2I-1. Supply volumes beyond 2020 were extrapolated to 2030 in the analysis.

Table 2I-1. Worldwide FT Diesel Supply Projections

	Volume	
Year	**Barrels/Day**	**Gallons/Year, millions**
2002	3,500	54
2010	88,000	1,349
2020	180,000	2,759

Assumptions

California's diesel fuel, called "CARB diesel" has more restrictive fuel quality specifications than federal diesel, called "EPA diesel." FT diesel can be blended with EPA diesel to produce a diesel fuel meeting CARB's requirements for an alternative diesel formulation.

The amount of FT diesel blended with EPA diesel is estimated from specifications for in-state diesel fuel that have been certified by CARB as an alternative diesel formulation. Typical values for the total aromatic content and cetane numbers for FT diesel and EPA diesel are shown in Table 2I-2. Based upon these specifications and a finished blended diesel with desired aromatic content and cetane number of 20 percent and 55, respectively, the ratio of FT diesel (FTD) needed to be blended with EPA diesel is 1:2 (one gallon of FTD is blended with 2 gallons of EPA diesel). The resulting mixture can be called FTD33. The desired aromatic and cetane values are within the ranges for alternative diesel formulation specifications certified by CARB.[3]

If the suitable blending ratio of FT diesel to EPA diesel is 1:2, the value of FT diesel as a blending stock can be calculated from the sum of the wholesale price of EPA diesel and two times (one gallon of FT diesel can be combined with two gallons of EPA diesel to produce three gallons of CARB diesel) the price differential between CARB diesel and EPA diesel.[4] For this example, the calculated FT diesel value is $0.90 per gallon (wholesale).

Table 2I-2. Diesel Fuel Specifications

Component	Percentage	Aromatic Content, %	Cetane No.	Wholesale Price/gallon, $
EPA Diesel	66.7	30	42.5	1.07-0.75
FT Diesel	33.3	0	80	1.21-0.85
Blended Diesel (FTD33)	100	20	55	1.12-.79

The wholesale cost differential between FT diesel and CARB diesel is about $.10 per gallon. If CARB diesel is $0.96/gallon, FT diesel is then estimated to be $1.06 per gallon.[5] Since the blending value of FT diesel brackets this cost, FT diesel can be an attractive blending component to produce a CARB diesel formulation.

Staff examined the cost effectiveness of FT diesel under a mature market condition, which may very well be just emerging for this fuel. A present value calculation was performed on the incremental cost of using FTD33 over the life of a heavy-duty vehicle compared to the use of conventional CARB diesel. Vehicle life was assumed to be 16 years. With the possible exception of a fuel price incremental, there were no other incremental costs related to vehicle acquisition or deployment of fueling infrastructure.

The analysis for a mature market assumes that the incremental retail cost of FT diesel is 5 to 10 cents per gallon higher than EPA diesel. The EPA diesel that would be blended with the FT diesel is assumed to be 5 cents per gallon lower than the cost of CARB diesel. A standard deviation in price of $.17 per gallon was used for high and low retail CARB diesel fuel prices.

Beginning in 2008, the use of FTD33 is ramped up to become the normal diesel fuel standard by 2019. At this future time, the entire diesel fuel supply sold in California becomes FTD33. Thus, in this scenario, one-third of the projected base case diesel demand would be met by FT diesel and the remaining balance provided by conventional petroleum diesel.

Results

Results at a diesel price of $1.48, $1.65 and $1.82 are shown in Tables 2I-3, 2I-4 and 2I-5, respectively. The results show that under mature cost conditions for FT diesel and EPA diesel, the use of FT diesel to produce a compliant CARB diesel can be an attractive option for reducing demand for diesel and producing consumer savings.

For the midpoint price (Table 2I-4), for the period 2002 to 2010, the results indicate that consumers would save $165 million using FTD33 compared to CARB diesel (expressed on a present value basis in year 2001 dollars). Government would experience no change in revenue since the excise tax rate and fuel economy are identical for either fuel. As shown in the table, savings grow in later years.

When the costs are evaluated for individual years, similar results are seen. In 2010, consumers would save about $79 million. Again, savings grow in later years.

FTD33 fuel would displace an increasing percentage of CARB diesel, starting out at 3.0 percent of the forecasted on- road diesel demand in 2010, growing to 33.0 percent in 2020 and 2030. Displacing each gallon of diesel using FTD33 would save $0.73 in 2010. The range narrows to a savings of up to $0.07 per gallon in 2020 and zero in 2030. These dollars are in year expended, and are not expressed as present values.

Key Drivers and Uncertainties

The projected demand for FT diesel depends on the following outcomes and assumptions.

- The worldwide production capacity for FT diesel must track the supply schedule shown in Table 2I-1. It is reasonable to assume that investment in additional production capacity is likely when crude oil prices are sustained at $20 per barrel or higher (current prices are well above this level). The pace of investment would be higher at higher oil prices.

- FT diesel will flow to California when its value is sufficiently attractive for distributors and refiners. There appears to be an economic advantage for refiners to use FT diesel to produce a diesel fuel meeting California's alternative diesel formulation requirements.

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[1] Durbin, T. D., et.al., Evaluation of the Effects of Alternative Diesel Fuel Formulations on Exhaust Emissions Rates and Reactivity, Final Report, Center for Environmental Research and Technology, University of California, Riverside, CA, April 1999,<www.cert.ucr.edu/research/pubs/99-ve-rt2p-001-fr.pdf>.

[2] Personal communication (e-mail) with Jim Caldwell, U.S. EPA, June 20, 2002. Baseline Diesel Requirements contained in Title 40 CFR 79.56(e)(3)(ii)(A).

[3] www.arb.ca.gov, Certified Alternative Diesel Formulations, February 2002.

[4] Example calculation for the value of FT diesel: Wholesale price of EPA diesel = $0.75/gallon, wholesale price of CARB diesel = $0.80/gallon, 1:2 blend ratio of FT diesel to EPA diesel; (.75 x 2/3) + FT value x 1/3) = .80; FT value = .90.

[5] The wholesale price of CARB diesel is derived from the long-term retail price used in the base case demand analysis, $1.65 per gallon. The retail price results from a (wholesale price + retail margin + federal excise tax + state excise tax) x (state sales tax rate). The wholesale price would include margins for producing and distributing the fuel to consumers, $.15 per gallon. The federal and state excise taxes for diesel fuel are $0.243 and $0.18 per gallon, respectively. A state sales tax rate of 7.75% was employed.

Table 2I-3

Summary of Analysis Results
Option 2I: Fischer-Tropsch Diesel

Case: FTD33; Fuel Price: $1.48

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$125	$125	$0	$0	$125	$125
2002 to 2020	$464	$464	$0	$0	$464	$464
2002 to 2030	$706	$706	$0	$0	$706	$706

Single Year Savings in Millions of 2001 Dollars

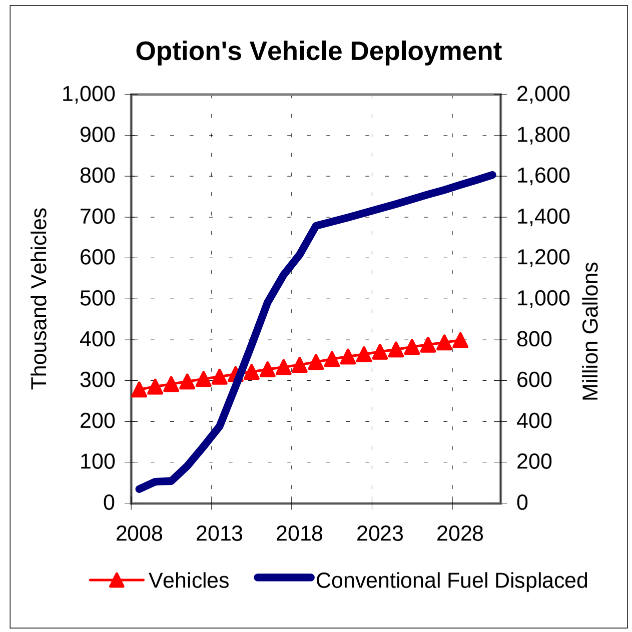
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	$60	$60	$0	$0	$60	$60
2020	$70	$70	$0	$0	$70	$70
2030	$81	$81	$0	$0	$81	$81.3

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.480
Low Fuel Price Estimate ($/gallon)	$1.480
For This Option:	
Vehicle Fuel Economy (mi/gallon)	6.5
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.463
Low Fuel Price ($/Gallon)	$1.463
Vehicle Life (years)	16
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

	Cumulative Over Time Period		Fuel Displaced in Year Indicated				
	Low	High	Year	Low	High	Low %	High %
2002 to 2010	282	282	2010	107	107	3.0%	3.0%
2002 to 2020	8,515	8,515	2020	1,377	1,377	33.0%	33.0%
2002 to 2030	23,516	23,516	2030	1,606	1,606	33.0%	33.0%



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	$0.56	$0.56	$0.00	$0.00	$0.56	$0.56
2020	$0.05	$0.05	$0.00	$0.00	$0.05	$0.05
2030	$0.05	$0.05	$0.00	$0.00	$0.05	$0.05

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

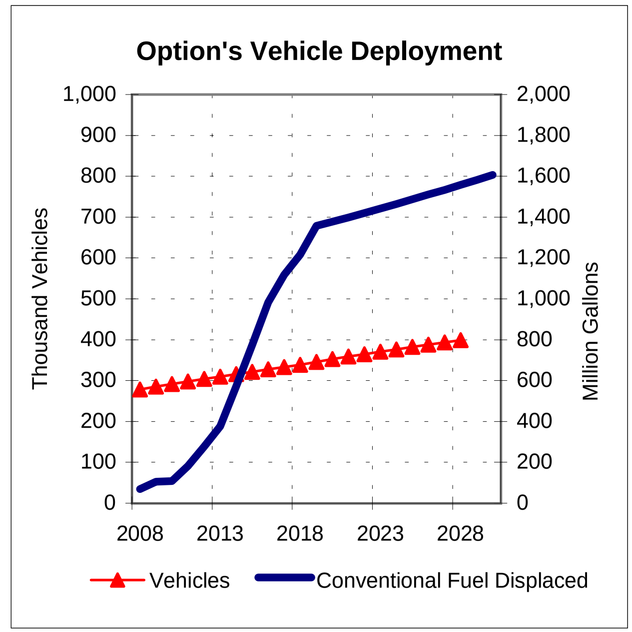
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$165	$165	$0	$0	$165	$165
2002 to 2020	$611	$611	$0	$0	$611	$611
2002 to 2030	$930	$930	$0	$0	$930	$930

Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.650
Low Fuel Price Estimate ($/gallon)	$1.650

Vehicle Fuel Economy (mi/gallon)	6.5
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.628
Low Fuel Price ($/Gallon)	$1.628
Vehicle Life (years)	16
Discount Rate (%)	5%

2010	$79	$79	$0	$0	$79	$79
2020	$92	$92	$0	$0	$92	$92
2030	$107	$107	$0	$0	$107	$107.1

	Low	High	Year	Low	High	Low %	High %
2002 to 2010	282	282	2010	107	107	3.0%	3.0%
2002 to 2020	8,515	8,515	2020	1,377	1,377	33.0%	33.0%
2002 to 2030	23,516	23,516	2030	1,606	1,606	33.0%	33.0%



	[1]	[2]	Low	High	[1]	[2]
2010	$0.73	$0.73	$0.00	$0.00	$0.73	$0.73
2020	$0.07	$0.07	$0.00	$0.00	$0.07	$0.07
2030	$0.07	$0.07	$0.00	$0.00	$0.07	$0.07

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.
[2] This result represents the opposite of [1].

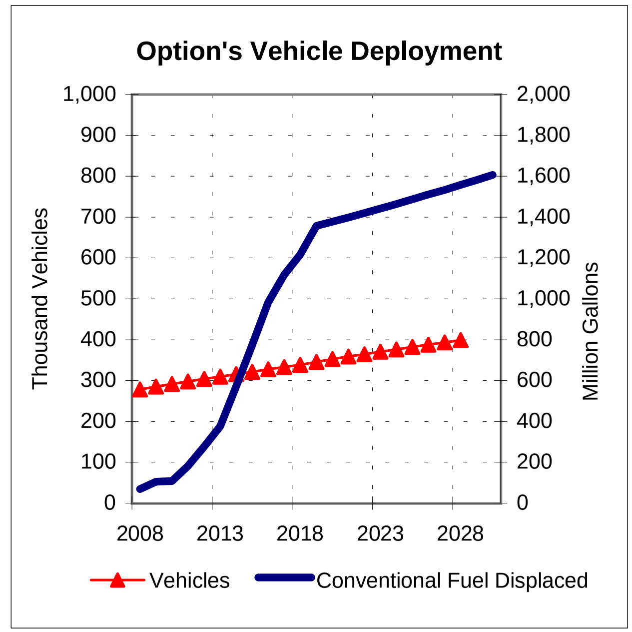
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2002 to 2020	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2002 to 2030	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0

Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.82
Low Fuel Price Estimate ($/gallon)	$1.82

Vehicle Fuel Economy (mi/gallon)	6.5
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.820
Low Fuel Price ($/Gallon)	$1.820
Vehicle Life (years)	16
Discount Rate (%)	5%

2010	$0.0	$0	$0.0	$0.0	$0.0	$0
2020	$0.0	$0	$0.0	$0.0	$0.0	$0
2030	$0.0	$0	$0.0	$0.0	$0.0	$0

	Low	High	Year	Low	High	Low %	High %
2002 to 2010	282	282	2010	107	107	3.0%	3.0%
2002 to 2020	8,515	8,515	2020	1,377	1,377	33.0%	33.0%
2002 to 2030	23,516	23,516	2030	1,606	1,606	33.0%	33.0%



	[1]	[2]	Low	High	[1]	[2]
2010	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2020	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2030	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Staff Paper on Option 2J
Biodiesel

Description

This option is the adoption of incentives to reduce the consumer cost of biodiesel fuel for use at 2 percent by volume as a lubricity agent (B2) and at 20 percent as a petroleum displacement blending component (B20) in diesel fuel for heavy-duty vehicles.

Background

Biodiesel fuels are typically made from soybean oils, rapeseed oil, animal fats or recycled cooking greases. Biodiesel is made by reacting any natural oils or fats with alcohol (usually methanol). It can be used in neat form (B100) or as a blendstock to extend the supply of conventional, petroleum-derived diesel (used at a 20 percent biodiesel to 80 percent conventional diesel, it is called B20). Using biodiesel in a more modest fraction of 2 percent by volume (called B2) can provide an alternative fuel lubricity option.[1]

Biodiesel has low sulfur levels, typically lower than year 2006 federal sulfur requirements, and can be used as a blend stock to reduce the overall sulfur content of some diesels. Biodiesel can be used in most applications in the same manner as conventional petroleum diesel. One notable exception is that special handling and heaters may be required in cold weather applications. Also, there may be some materials compatibility issues with seals and gaskets in engines manufactured before 1994. At the present time, the practice is to limit the percentage of biodiesel to no more than 20 percent (B20) to avoid these problems.

When blended at 20 percent with conventional diesel fuel, the resultant mixture has generally demonstrated lower or comparable emissions of total hydrocarbons, carbon monoxide, and particulate matter compared to CARB diesel.[2] The emission level for NO_x is comparable to the level for CARB diesel[2] or slightly higher.[3,4] The range in emission levels seems to vary, depending on the type of feedstock used to produce the biodiesel and the quality of the petroleum diesel used in the mixture.

Neat biodiesel (B100) has a lower energy content than conventional diesel. The energy content (lower heating value) of biodiesel ranges from about 117,000 to 124,000 Btu per gallon[5] while conventional CARB diesel fuel is about 133,000 Btu per gallon.

The U.S. Department of Energy's Office of Transportation Technologies has estimated the net energy balance for biodiesel. For every gallon of petroleum fuel used to produce it, 3.37 gallons of biodiesel are produced.[6]

Status

The supply of biodiesel is limited today by its significantly higher production cost. When used in its pure form (B100), biodiesel costs between $1.25 and $2.25 per gallon depending on purchase volume and delivery costs.[7] Presently, B20 costs 13 to 22 cents per gallon more than petroleum diesel.[8] However, federal legislation, H.R. 4843 (Hulshof), has been introduced to provide a $0.01 per gallon reduction in fuel excise tax for each percentage point of biodiesel used to blend in diesel fuel, up to a limit of 20 percent. If enacted, this legislation would effectively reduce the cost of B100 for blenders by up to $1.00 per gallon. Since this is pending legislation at this time, this effect was not included in the spreadsheet analysis reported below.

The U.S. DOE is conducting research to reduce the cost of producing biodiesel and to expand supplies using novel feed stocks and new production technologies. A portion of the work is directed at reducing NO_x emissions.

The projected national supply of biodiesel is shown in Table 2J-1.

Table 2J-1. Projected Biodiesel Supply[9]

Year	Volume (millions of gallons)
2002	4
2010	1,000
2020	6,000

Assumptions

Two biodiesel scenarios are examined. The cases separately assume that B2 and B20 become an industry standard for California diesel fuel. The amount of biodiesel used in any given year is assumed to be limited to a maximum of 10 percent of national biodiesel supply. In the first case, 2 percent biodiesel is blended with CARB diesel (called B2) as a lubricity additive, beginning in 2008. In the second case, biodiesel is used as a blending agent to extend CARB diesel supplies, beginning at 2 percent blending rate in 2008 and gradually increasing to 20 percent by 2015. In the earlier years, the national supply of biodiesel may limit the volume that could be used as a blending agent, although supplies should be sufficient for the full 20 percent blending rate by 2015.

Since biodiesel can be used in existing diesel engines without modification at levels of B20 and below, there is no incremental cost related to vehicle purchase. The existing diesel fuel infrastructure can also store and dispense B20 without modification.

In this analysis, staff used literature estimates of the cost of biodiesel, and determined the cost of B2 and B20 by ratio. For the near term analysis we used B2, with a neat biodiesel (B100) wholesale price range of $1.25 to $1.75 (includes a delivery charge of $0.04 per gallon).[10] For the mature technology analysis we used B20, with a mature market neat biodiesel (B100) wholesale price of $1.25 (includes the same delivery charge). These costs resulted in B2 wholesale prices about $0.01 per gallon greater than CARB diesel and B20 prices about $0.02 to $0.09 per gallon greater than CARB diesel.

The lower heating value we used for B100 varies depending on the type of bio material used. We used a mid point value of 121,000 Btu/gallon. This heating value is consistent with volumetric fuel economy of conventional diesel fuel and less than CARB diesel fuel, which is 133,000 Btu/gallon.[11]

Although opportunities are now emerging for the use of biodiesel in site specific applications for B20, the potential for large-scale use will require considerable research and development efforts to reduce the price of B100 to a point where it could become competitive with petroleum-based diesel. A mature market scenario is used to model the use of biodiesel at up to a 20 percent blend level in CARB diesel. The scenario assumes that 10 percent of the projected national supply of B100 would be used in California to gradually increase the amount of biodiesel blended with petroleum diesel until B20 becomes a statewide, industry standard.

This scenario calculates the incremental cost of B20 based upon a B100 wholesale cost of $1.25 per gallon. It would then be blended with a CARB diesel fuel. The estimated B20 wholesale price range is about $0.88 to $1.13 per gallon. A standard deviation in price of $.17 per gallon was used for high and low retail diesel fuel prices. No incremental costs are assumed to be required for vehicle acquisition or fuel infrastructure.

No incremental costs are assumed to be required for vehicle acquisition or fuel infrastructure.

Results

The analysis results are summarized in Tables 2J-2 to 2J-7. Each fuel is discussed separately. Negative values in the table are costs to the consumer and are shown with parentheses.

B2, Lubricity Option. Tables 2J-2 to 2J-4 display the summary results for B2. Using biodiesel at 2 percent as an alternative blending component is predicted to cost more than CARB diesel.

Table wJ-3 shows the results for the midpoint fuel price. Between 2008 and 2010, the results indicate that the fuel would cost $89 million more than CARB diesel. Because the excise tax rate and fuel consumption rate are both the same for either fuel, there would be no change in government revenue. As shown in the table, costs grow in later years.

When the costs are evaluated for individual years, similar results are seen. In 2010, consumers would lose about $43 million. In 2020, consumers would lose about $51 million and in 2030, consumers would lose about $59 million. Since government revenue would not be affected, these values also represent net effects.

On the other hand, since B2 would be blended in all of the diesel pool under this option, it would displace 2 percent of the on-road diesel forecasted to be used in the 2010 to 2030 time period. Displacing each gallon of diesel using B2 would cost $0.60 to $0.61. These dollars are in year expended, and are not expressed in terms of present value.

B20, CARB Diesel Blending Agent. Tables 2J-5 to 2J-7 display the summary results for B20 as a blended diesel fuel. Negative values in the table are costs to the consumer and are shown with parentheses. Using biodiesel at 20 percent as an alternative blending component is predicted to cost more than CARB diesel.

Table 2J-6 shows results for the midpoint fuel price. For the period 2002-2010, B20 would cost $410 million more than CARB diesel. At the same time, government would experience about a $1 million increase in revenue because the fuel consumption rate for B20 is slightly higher than for CARB diesel, producing additional fuel excise taxes. The greater fuel use is due to the lower volumetric energy content of B20 compared to CARB diesel values. As shown in the table, costs grow in later years. These results are all on a net present value basis, expressed in year 2001 dollars.

When the costs are evaluated for individual years, similar results are seen. In 2010, consumers would lose $197 million while government revenue would gain $0.7 million due to the slightly greater fuel consumption for B20. Net losses would be approximately the same as the consumer impact but decreased by to the growth in excise tax revenue. Again, values would grow in later years. The individual year results are not expressed as present values.

B20 would displace approximately 3.0 percent of the on road diesel forecasted to be used in the 2010, growing to 19.5 percent by 2020 and remaining at that level until 2030. Because the energy density of B20 is slightly lower than CARB diesel, slightly more fuel must be burned and the net diesel displacement is less than 20 percent. Displacing each gallon of diesel using B20 would cost between $0.32 to $1.85 in 2010 and $0.32 in 2020 and 2030. These dollars are in year expended, and are not on a net present value basis.

Key Drivers and Uncertainties

- Although the projected supply of biodiesel appears sufficient, demand in other regions of the country would have to increase to support the required investment in production capacity.
- It is likely that any reduction in fuel excise tax used to support the higher cost of biodiesel would have to be offset by higher revenues from another source.
- The long-term production cost of biodiesel is expected to decrease as production technology improves, lower cost feedstocks are developed, and production scale-up reduces unit costs.

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[1] U. S. DOE, Office of Transportation Technologies, http://www.ott.doe.gov/biofuels/renewable_diesel.html.

[2] Thomas D. Durbin, et. al., Final Report, Evaluation of the Effects of Biodiesel and Biodiesel Blends on Exhaust Emission Rates and Reactivity-2, Center for Environmental Research and Technology, College of Engineering, University of California, Riverside, CA, August 2001.

[3] Clark, N.N., et al., Transient Emissions Comparisons of Alternative Compression Ignition Fuels, West Virginia University, submitted to 1999 SAE Congress.

[4] Starr, M.E., Influence on Transient Emissions at Various Injection Timings, using Cetane Improvers, Biodiesel, and Low Aromatic Fuels, 1997, SAE Technical Paper No. 972904.

[5] U.S. DOE, Alternative Fuels Data Center, http://www.afdc.doe.gov/altfuel/bio_papers.html, May 2002; The stated range comes from different rounded values published in papers found at this website.

[6] U.S. DOE, Office of Transportation Technologies web site, “Biodiesel Benefits.”

[7] U.S. DOE, Clean Cities Alternative Fuel Information Series, Fact Sheet, May 2001.

[8] Ibid.

[9] Supply projections based upon staff communication between Gary Yowell and Dr. K. Shaine Tyson, National Renewable Energy Laboratory, August 2001.

[10] The charge for tank truck delivery varies by delivery distance; for an 8,000 gallon load, $0.015/gal for 10 miles, $0.0252 for 40 miles, $0.0404 for 100 miles, $0.0698 for 250 miles (personal communication between Alan Argentine and Redwood Oil Company, Santa Rosa, CA, July 2002); an average of $0.04/gal is used in this analysis.

[11] Biodiesel—the Clean, Green Fuel for Diesel Engines, <<www.afdc.doe.gov/pdfs/5450.pdf>>.

Table 2J-2

Summary of Analysis Results
Option 2J: Biodiesel

Case: B2; Fuel Price: $1.48

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($62)	($62)	$0	$0	($62)	($62)
2002 to 2020	($232)	($232)	$0	$0	($232)	($232)
2002 to 2030	($354)	($354)	$0	$0	($354)	($354)

Single Year Savings in Millions of 2001 Dollars

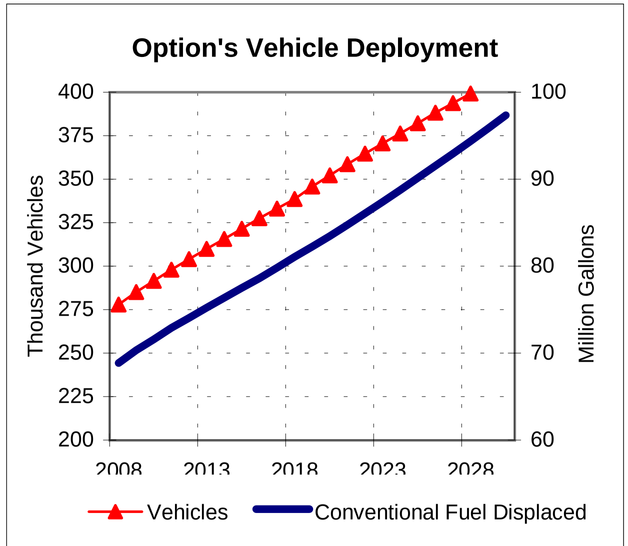
	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($30)	($30)	$0	$0	($30)	($30)
2020	($35)	($35)	$0	$0	($35)	($35)
2030	($41)	($41)	$0	$0	($41)	($41)

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.480
Low Fuel Price Estimate ($/gallon)	$1.480
For This Option:	
Vehicle Fuel Economy (mi/gallon)	6.5
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.489
Low Fuel Price ($/Gallon)	$1.489
Vehicle Life (years)	16
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	211	211	2010	72	72	2.00%	2.00%
2002 to 2020	992	992	2020	83	83	2.00%	2.00%
2002 to 2030	1,901	1,901	2030	97	97	2.00%	2.00%



2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.41)	($0.41)	$0.00	$0.00	($0.41)	($0.41)
2020	($0.42)	($0.42)	$0.00	$0.00	($0.42)	($0.42)
2030	($0.42)	($0.42)	$0.00	$0.00	($0.42)	($0.42)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2J-3

Summary of Analysis Results
Option 2J: Biodiesel

Case: B2; Fuel Price: $1.65

RESULTS OF THE ANALYSIS:

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($75)	($75)	$0	$0	($75)	($75)
2002 to 2020	($285)	($285)	$0	$0	($285)	($285)
2002 to 2030	($434)	($434)	$0	$0	($434)	($434)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
2010	($36)	($36)	$0	$0	($36)	($36)
2020	($43)	($43)	$0	$0	($43)	($43)
2030	($50)	($50)	$0	$0	($50)	($50)

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	211	211	2010	72	72	2.00%	2.00%
2002 to 2020	992	992	2020	83	83	2.00%	2.00%
2002 to 2030	1,901	1,901	2030	97	97	2.00%	2.00%

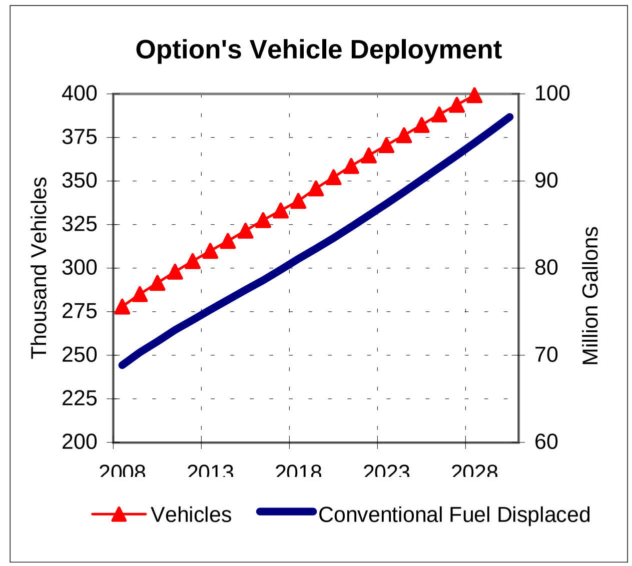
2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits		Change in Gov't Revenue		Net Benefits	
	[1]	[2]	Low	High	[1]	[2]
2010	($0.51)	($0.51)	$0.00	$0.00	($0.51)	($0.51)
2020	($0.52)	($0.52)	$0.00	$0.00	($0.52)	($0.52)
2030	($0.52)	($0.52)	$0.00	$0.00	($0.52)	($0.52)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.
[2] This result represents the opposite of [1].

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.650
Low Fuel Price Estimate ($/gallon)	$1.650
For This Option:	
Vehicle Fuel Economy (mi/gallon)	6.5
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.661
Low Fuel Price ($/Gallon)	$1.661
Vehicle Life (years)	16
Discount Rate (%)	5%



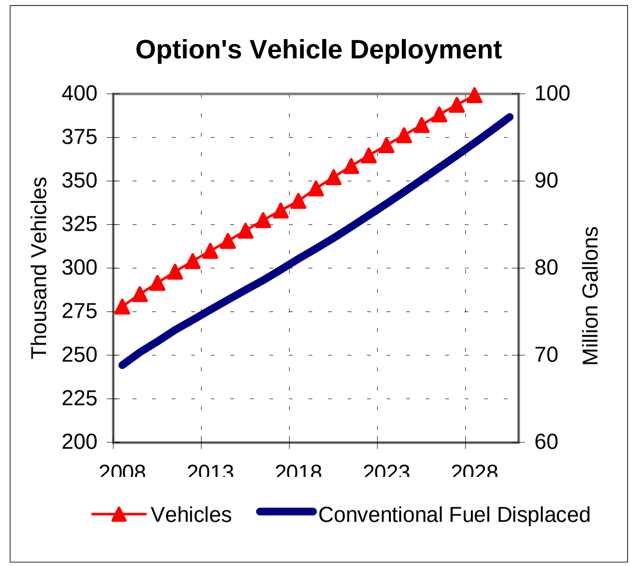
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($89)	($89)	$0.0	$0.0	($89)	($89)
2002 to 2020	($337)	($337)	$0.0	$0.0	($337)	($337)
2002 to 2030	($514)	($514)	$0.0	$0.0	($514)	($514)

Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.82
Low Fuel Price Estimate ($/gallon)	$1.82

Vehicle Fuel Economy (mi/gallon)	6.5
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.833
Low Fuel Price ($/Gallon)	$1.833
Vehicle Life (years)	16
Discount Rate (%)	5%

2010	($43)	($43)	$0.0	$0.0	($43)	($43)
2020	($51)	($51)	$0.0	$0.0	($51)	($51)
2030	($59)	($59)	$0.0	$0.0	($59)	($59)

	Low	High	Year	Low	High	Low %	High %
2002 to 2010	211	211	2010	72	72	2.00%	2.00%
2002 to 2020	992	992	2020	83	83	2.00%	2.00%
2002 to 2030	1,901	1,901	2030	97	97	2.00%	2.00%



	[1]	[2]	Low	High	[1]	[2]
2010	($0.60)	($0.60)	$0.00	$0.00	($0.60)	($0.60)
2020	($0.61)	($0.61)	$0.00	$0.00	($0.61)	($0.61)
2030	($0.61)	($0.61)	$0.00	$0.00	($0.61)	($0.61)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.
[2] This result represents the opposite of [1].

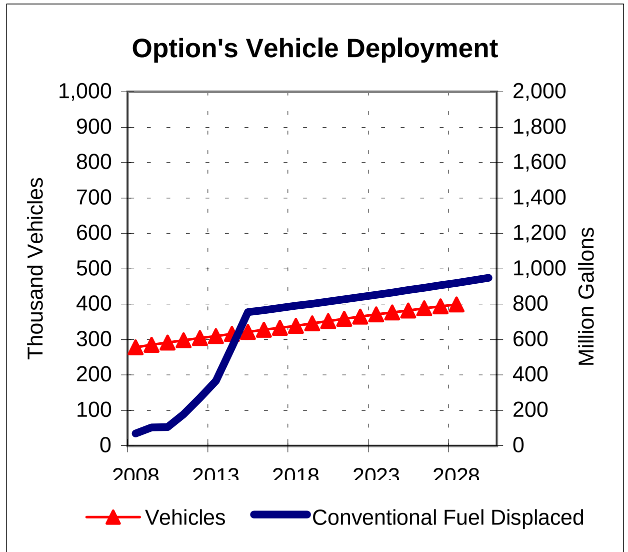
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($664)	($664)	$1	$1	($663)	($663)
2002 to 2020	($2,615)	($2,615)	$88	$88	($2,526)	($2,526)
2002 to 2030	($4,045)	($4,045)	$216	$216	($3,829)	($3,829)

Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.480
Low Fuel Price Estimate ($/gallon)	$1.480

Vehicle Fuel Economy (mi/gallon)	6.4 - 6.5
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.57
Low Fuel Price ($/Gallon)	$1.57
Vehicle Life (years)	16
Discount Rate (%)	5%

2010	($318)	($318)	$0.7	$0.7	($318)	($318)
2020	($412)	($412)	$11.8	$11.8	($400)	($400)
2030	($480)	($480)	$13.7	$13.7	($467)	($467)

	Low	High	Year	Low	High	Low %	High %
2002 to 2010	279	279	2010	106	106	3.0%	3.0%
2002 to 2020	6,354	6,354	2020	814	814	19.5%	19.5%
2002 to 2030	15,219	15,219	2030	949	949	19.5%	19.5%



	[1]	[2]	Low	High	[1]	[2]
2010	($3.01)	($3.01)	$0.01	$0.01	($3.00)	($3.00)
2020	($0.51)	($0.51)	$0.01	$0.01	($0.49)	($0.49)
2030	($0.51)	($0.51)	$0.01	$0.01	($0.49)	($0.49)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.
[2] This result represents the opposite of [1].

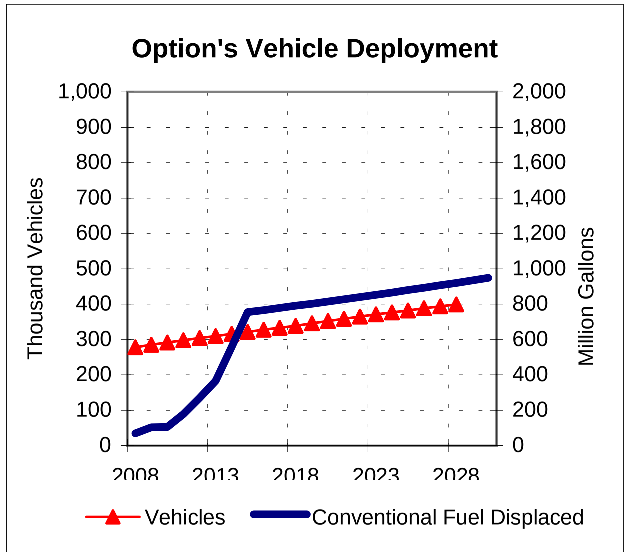
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($410)	($410)	$1	$1	($409)	($409)
2002 to 2020	($1,684)	($1,684)	$88	$88	($1,596)	($1,596)
2002 to 2030	($2,635)	($2,635)	$216	$216	($2,418)	($2,418)

Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.650
Low Fuel Price Estimate ($/gallon)	$1.650

Vehicle Fuel Economy (mi/gallon)	6.4 - 6.5
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.704
Low Fuel Price ($/Gallon)	$1.704
Vehicle Life (years)	16
Discount Rate (%)	5%

2010	($197)	($197)	$0.7	$0.7	($196)	($196)
2020	($274)	($274)	$11.8	$11.8	($262)	($262)
2030	($319)	($319)	$13.7	$13.7	($305)	($305)

	Low	High	Year	Low	High	Low %	High %
2002 to 2010	279	279	2010	106	106	3.0%	3.0%
2002 to 2020	6,354	6,354	2020	814	814	19.5%	19.5%
2002 to 2030	15,219	15,219	2030	949	949	19.5%	19.5%



	[1]	[2]	Low	High	[1]	[2]
2010	($1.86)	($1.86)	$0.01	$0.01	($1.85)	($1.85)
2020	($0.34)	($0.34)	$0.01	$0.01	($0.32)	($0.32)
2030	($0.34)	($0.34)	$0.01	$0.01	($0.32)	($0.32)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.

[2] This result represents the opposite of [1].

Table 2J-7

RESULTS OF THE ANALYSIS:
Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits					
	[1]	[2]	Low	High	[1]	[2]
2002 to 2010	($156)	($156)	$1	$1	($154)	($154)
2002 to 2020	($754)	($754)	$88	$88	($665)	($665)
2002 to 2030	($1,225)	($1,225)	$216	$216	($1,008)	($1,008)

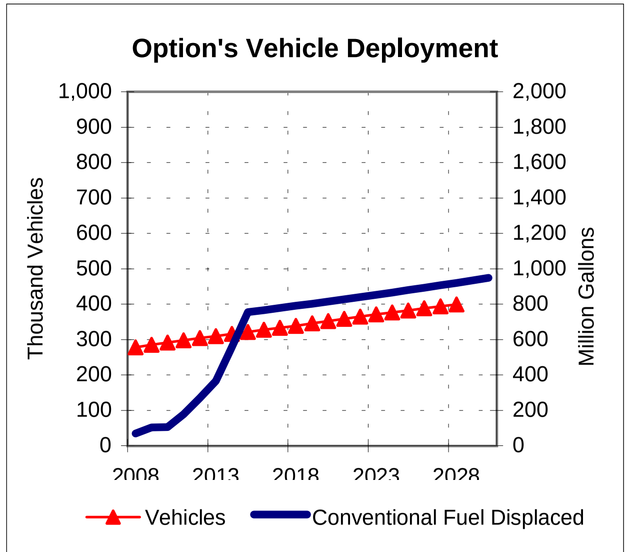
2010	($75)	($75)	$0.7	$0.7	($75)	($75)
2020	($136)	($136)	$11.8	$11.8	($124)	($124)
2030	($158)	($158)	$13.7	$13.7	($144)	($144)

MAJOR INPUT ASSUMPTIONS:

For Conventional Vehicles:	
Fuel Economy (mi/gallon)	6.5
High Fuel Price Estimate ($/gallon)	$1.82
Low Fuel Price Estimate ($/gallon)	$1.82
For This Option:	
Vehicle Fuel Economy (mi/gallon)	6.4 - 6.5
High Incremental Cost ($ per vehicle)	$0
Low Incremental Cost ($ per vehicle)	$0
High Fuel Price ($/Gallon)	$1.84
Low Fuel Price ($/Gallon)	$1.84
Vehicle Life (years)	16
Discount Rate (%)	5%

Conventional Fuel Displaced (Million Gallons)

Cumulative Over Time Period	Low	High	Year	Fuel Displaced in Year Indicated: Low	High	Low %	High %
2002 to 2010	279	279	2010	106	106	3.0%	3.0%
2002 to 2020	6,354	6,354	2020	814	814	19.5%	19.5%
2002 to 2030	15,219	15,219	2030	949	949	19.5%	19.5%



2001 Dollars Per Gallon of Conventional Fuel Displaced
Change in Gov't Revenue

	[1]	[2]	Low	High	[1]	[2]
2010	($0.71)	($0.71)	$0.01	$0.01	($0.71)	($0.71)
2020	($0.17)	($0.17)	$0.01	$0.01	($0.15)	($0.15)
2030	($0.17)	($0.17)	$0.01	$0.01	($0.15)	($0.15)

[1] This result represents the minimum of lower fuel and incremental capital cost range versus higher fuel and incremental capital cost range.
[2] This result represents the opposite of [1].

Staff Paper on Option 3A
Gasoline Tax

Description

This option examines the effect of increasing the tax on gasoline in California by 50 cents per gallon for the period 2003-2020.

Background

A higher gasoline tax would reduce the consumption of gasoline through two mechanisms. First, the additional tax would increase the per-mile cost of driving, reducing vehicle miles traveled. Second, the tax would provide an incentive for vehicle owners to purchase a more fuel-efficient vehicle, as this would reduce exposure to the tax. This second mechanism, which would take place over time, would lead to greater reductions in gasoline demand in the medium and long term relative to the short term.

Status

Current gasoline excise taxes (state and federal) amount to around 36 cents per gallon in California. When proposals have been made in California and other states for an increase in fuel taxes, the higher tax is meant as a funding mechanism, usually for transportation related projects. Staff is not aware of any serious attempt by policymakers in the U.S. to increase fuel taxes for purposes of reducing gasoline consumption since the carbon tax proposal during the first term of the Clinton administration.

Assumptions

The Commission's CALCARS model was used to simulate this option. CALCARS is a behaviorally-based vehicle choice, usage, and demand model estimated specifically for California. The model predicts at the household level, using 57 types of households that vary by annual income, number of members, and number of employed members.

The price of gasoline was increased by 50 cents, and this increase affected miles driven, vehicle choice, and vehicle demand. The higher gasoline tax was assumed to affect personal vehicles only, as the models used by the Commission for commercial fleet and freight energy demand are currently not behaviorally based.

Revenues from the tax would presumably provide a benefit to California in some form (perhaps through a rebate or a reduction in another type of state tax) and are therefore shown as a benefit in Table 3A-1.

Results

Table 3A-1 shows the net benefit results for consumers and the impact on government revenues (in this case a positive net benefit), in present value terms, for 2010, 2020, and 2030, for a 5 percent discount rate. These calculations are net amounts relative to the base case forecast. The negative consumer benefits (also known as the change in consumer surplus) are equal to the higher cost per gallon of gasoline times the new (lower) level of gasoline demand, plus a "deadweight" loss to society. The deadweight loss is composed of the lost benefits to motorists due to reduced driving and the costs to those who switch to a less-preferred (more fuel-efficient) vehicle.

Government revenues increase by the new (lower) level of gasoline consumption times 50 cents, plus the reduction in the cost of highway maintenance (the decrease in VMT times 0.4 cents), minus the excise tax revenues lost due to decreased gasoline consumption. The sum of these two impacts is shown in Table 3A-2 as "Direct Non-Environmental Net Benefits," and represents direct benefits excluding the "external" beneficial effects of reduced driving and gasoline demand (e.g., less congestion, less gasoline-related pollution). These entries are negative, but once environmental effects are considered, total direct benefits may be positive.

Key Drivers and Uncertainties

- The future price of gasoline would play a key role in the impact of a higher gasoline tax. If gasoline prices are significantly higher than what is projected in the base case forecast, the impact of a higher tax on gasoline demand would be reduced, since discretionary driving (the first type of driving to be affected by higher gasoline prices) would already be at a lower level.

- Long-run price elasticities (as vehicle owners purchase more fuel efficient vehicles over time) are higher in absolute magnitude, although at the lower end of the range estimated in the literature. This is partly due to the assumption made for this analysis that manufacturers offer the same fleet mix in California relative to the base case forecast. If manufacturers were to respond by offering vehicles with additional fuel economy technologies, long-run price elasticities would be higher. It is quite possible that there would be additional effects not captured by CALCARS. In the long term, households may respond to higher gasoline prices by changing location (e.g., to be closer to transit or to reduce work commute miles) and government may be more likely to promote land use policies that reduce travel costs (e.g., transit oriented development). Such effects would lead to further decreases in travel and fuel use.

Table 3A-1

Summary of Analysis Results

Option 3A: Gasoline Tax

($1.64 per gallon gasoline)

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	($38,156)	$36,247	($1,909)
2002 to 2020	($73,599)	$69,804	($3,795)
2002 to 2030	($98,478)	$93,324	($5,154)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	($6,211)	$6,012	($199)
2020	($7,074)	$6,833	($241)
2030	($8,087)	$7,801	($286)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	5,270	2010	745	4.6%
2002 to 2020	13,525	2020	892	4.8%
2002 to 2030	23,313	2030	1,051	4.9%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	($8.53)	$8.07	($0.46)
2020	($8.12)	$7.67	($0.45)
2030	($7.87)	$7.42	($0.45)

Staff Paper on Option 3B
Marginal Cost Pricing for Auto Insurance

Description

This option examines the effects of implementing a "pay-at-the-pump" (PATP) auto insurance system, where a portion of insurance is paid through a fuel surcharge, and a "pay-as-you-drive" (PAYD) system, where a portion of insurance is paid through a per-mile charge.

Background

In recent years, PATP and PAYD insurance have attracted a great deal of attention as alternatives to the current auto insurance market. PATP insurance proposals require that at least some portion of auto insurance be covered through a higher fuel tax, with the rest paid either as an increment to registration fees or directly to an insurance company. PATP is touted as a money saver for currently insured motorists, since uninsured motorists would have to pay at least some insurance (through the fuel surcharge), so that uninsured motorist coverage now paid by insured drivers would be reduced or eliminated.

PAYD insurance proposals involve a per-mile charge that would be paid directly to auto insurance companies. In practice, PAYD would likely require premiums to be paid in advance (as is the case under the current system), with vehicle owners either paying an additional amount per billing period or receiving a rebate, depending on vehicle miles traveled (VMT).[1]

An appealing aspect of both PATP and PAYD is that these measures would more closely link the cost of insurance to VMT. The more miles driven, all else equal, the greater the exposure to accidents. The current system of pricing is inefficient since insurance is perceived by motorists as a fixed cost, whereas it is quite likely that at least a portion of accident risk is a variable component related to VMT.[2] Therefore, through more efficient pricing of insurance, PATP and PAYD have potential welfare benefits.

Because PATP and PAYD insurance would increase the marginal cost of driving, VMT and gasoline use should decrease, since many motorists would likely drive less. In addition, in the case of PATP, many motorists would switch to a more efficient vehicle to reduce exposure to the higher tax (either within the household's current fleet or through replacement of a currently held vehicle), so that average vehicle fuel economy would increase. Therefore, PATP and PAYD act as travel demand measures, and external costs related to both driving (e.g., congestion) and gasoline use (e.g., global warming) would be expected to fall. Furthermore, these benefits may not require an increase in private costs for the average motorist.

Status

PATP generated quite a bit of interest in California in the early 1990's, and legislation was drafted to examine its workability. Since then, no serious attempt has been made by policymakers in the U.S. to implement a PATP system. PAYD has generated enough interest that the Federal Highway Administration's Value Pricing Program funded two PAYD pilot projects in fiscal year 2001.

Assumptions

The Commission's CALCARS model was used to simulate this option. CALCARS is a behaviorally-based vehicle choice, usage, and demand model estimated specifically for California. The model predicts at the household level, using 57 types of households that vary by annual income, number of members, and number of employed members.

In this analysis, the minimum amount of liability insurance required by California law is paid through a fuel surcharge, beginning in 2003. Vehicle fixed costs are therefore reduced while marginal costs increase. In previous work, the cost for this minimum amount of insurance was estimated to be between $150 and $400 in California, depending on the insurance company and the geographic area.[3] In this simulation, the cost was assumed to be $250 in 2003. This translated to roughly 2.1 cents per vehicle mile traveled by personal vehicles, collected through a gasoline surcharge in the case of PATP and through a rebate/additional fee system in the case of PAYD.

The PATP incentive to drive/purchase a more fuel-efficient vehicle increases average fuel efficiency from year to year, effectively reducing the amount collected per mile. Therefore, it was necessary to increase this surcharge slightly every year to keep the amount collected per mile constant, from 44 cents per gallon at the beginning of the forecast period to almost 45 cents by 2030. At the same time, fixed costs per vehicle were reduced by $250 in 2003, adjusted upward slightly through the forecast period as VMT per vehicle increased.[4] Note that the critical assumption that must be made is that the portion of accident risk transferred to a marginal cost is proportional to VMT.

Since it is required by law, it was assumed that all drivers in California would carry minimum insurance without PATP or PAYD.

PATP was assumed to affect personal vehicles only, as the models used by the Energy Commission for commercial fleet and freight energy demand are currently not behaviorally based.

Results

Analysis results are displayed in Table 3B-1 for PATP and in Table 3B-2 for PAYD. Gasoline demand reductions relative to the base case forecast are greater for PATP than for PAYD, due to the incentive that PATP creates to drive more fuel efficient vehicles. Due to this incentive, percentage reductions in gasoline demand from PATP increase over time (unlike PAYD) and percentage reductions in VMT (not shown) are smaller than those for gasoline demand.[5]

Since the average increases in operating cost and decreases in fixed cost are the same for PATP and PAYD, net consumer benefits are virtually identical. The gain in economic efficiency that would be predicted by economic theory is reflected in the positive net benefits for consumers shown in the tables. These benefits are a net of the reduction in direct payments to insurance companies and the burden of higher operating costs. The average motorist now incorporates accident risk in his marginal driving decisions and is able to reduce his total cost of insurance by driving less—an option not available without marginal cost pricing of insurance. On a per-vehicle basis, net consumer benefits from PATP and PAYD average between $3 and $4 per year.

Government revenues decrease by the loss in excise taxes due to reduced gasoline demand, minus the reduction in the cost of highway maintenance (the decrease in VMT times 0.4 cents). The sum of these two impacts (Net Direct Benefits) represents direct benefits excluding the "external" beneficial effects of reduced driving and gasoline demand (e.g., less congestion, less gasoline-related pollution). These entries are negative, but once environmental effects are considered, total direct benefits may be positive.

Finally, Tables 3B-1 and 3B-2 show the amount of benefit (cost) per gallon of gasoline displaced for 2010, 2020, and 2030. Note that these are non-discounted values and apply to specific years. For example, the entries for "Consumer Benefit" for 2020 are non-discounted projected gains in consumer surplus for this year divided by the projected reductions in gasoline demand due to PATP and PAYD in 2020.

Key Drivers and Uncertainties

- The responsiveness of motorists to higher operating costs will determine the magnitude of net consumer benefits for PATP and PAYD. The more responsive are drivers, the higher the level of net consumer benefits (and the higher the reduction in VMT and gasoline use). However, if we assume all motorists carry minimum insurance in the base case forecast, consumer net benefits will always be positive, given the assumptions made here (they would be zero if there were absolutely no response to higher operating costs). That is, the average consumer will always be better off. Of course, this does not mean that every motorist would be better off. Those who drive many more miles than the average could end up with higher insurance costs and, under PATP, drivers of vehicles with very low fuel efficiency could be adversely affected, unless a mechanism were implemented to address differences in fuel efficiency.

- If we allow for the possibility that there could continue to be a significant number of uninsured drivers in California, it is likely that PATP would have even more favorable welfare impacts for insured motorists. The fuel surcharge would force uninsured drivers to pay at least some of the costs that they impose on the insured. The current charge for uninsured motorist coverage that is part of liability insurance could then be reduced or eliminated. On the other hand, such a system would have adverse welfare impacts for uninsured drivers.

- A PAYD system has advantages over PATP because of its flexibility. The amount charged per mile could be varied by insurance companies depending on specific customer characteristics and/or on the type and amount of auto travel. In addition, unlike PATP, PAYD would not penalize owners of less fuel-efficient vehicles (although PATP could be set up to avoid such an inequity through fees and rebates). PAYD also avoids the need to address complications such as out-of-state motorists and potential adverse impacts on the California economy created by higher gasoline prices.

- This analysis assumes a risk cost transferred to vehicle operating cost of 2.1 cents per mile throughout the forecast period. At present, there is no definitive empirical work available to justify any specific cost per mile (although it is certainly greater than zero), and such work would be required before PATP or PAYD could be implemented. This is a key point to emphasize—charging an amount per mile different from the true marginal cost per mile could lead to an even more economically inefficient system than what we currently have. In addition, even assuming that 2.1 cents is a reasonable estimate at the present time, this value could certainly decrease in the future as autos continue to become safer. If this were the case, the net benefits presented here, as well as the reductions in gasoline demand and VMT, would be overstated (although still positive).

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[1] For a further description of implementation, see: Litman, Todd (1997), "Distance-based Vehicle Insurance as a TDM Strategy," *Transportation Quarterly* (51:3).

[2] Insurance companies do currently charge higher premiums for relatively high-VMT drivers to some extent. However, the steps over which the premium remains constant are extremely wide. In addition, insurance companies have no way of ensuring higher premiums for such drivers, since they now depend on the insured to report estimated miles traveled.

[3] Kavalec, C., and J. Woods (1999), "Toward Marginal Cost Pricing of Accident Risk: the Energy, Travel, and Welfare Impacts of Pay-at-the-Pump Auto Insurance," *Energy Policy* (27:6).

[4] The risk cost per mile, 2.1 cents, was assumed constant throughout the forecast period. As income per household is projected to increase, VMT per vehicle increases slightly. Therefore, the fixed cost reduction was increased from $250 to a maximum of $255 to account for the increase.

[5] This result represents a "rebound" effect. The switch to more efficient vehicles reduces the impact of higher gasoline prices on vehicle fuel cost per mile.

Table 3B-1

Summary of Analysis Results

Option 3B: Marginal Cost Pricing for Auto Insurance

(Pay-at-the-Pump, $1.64 per gallon gasoline)

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$523	($902)	($379)
2002 to 2020	$1,006	($1,862)	($856)
2002 to 2030	$1,348	($2,575)	($1,227)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$86	($164)	($78)
2020	$99	($202)	($103)
2030	$114	($241)	($127)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	4,281	2010	610	3.8%
2002 to 2020	11,094	2020	739	4.0%
2002 to 2030	19,270	2030	879	4.1%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$0.14	($0.27)	($0.13)
2020	$0.13	($0.27)	($0.14)
2030	$0.13	($0.27)	($0.14)

Table 3B-2

Summary of Analysis Results

Option 3B: Marginal Cost Pricing for Auto Insurance

(Pay-as-you-Drive, $1.64 per gallon gasoline)

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$522	($693)	($171)
2002 to 2020	$1,004	($1,328)	($324)
2002 to 2030	$1,346	($1,771)	($425)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$86	($114)	($28)
2020	$99	($129)	($30)
2030	$114	($148)	($34)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	3,468	2010	459	2.8%
2002 to 2020	8,365	2020	519	2.8%
2002 to 2030	13,958	2030	594	2.8%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$0.19	($0.25)	($0.06)
2020	$0.19	($0.25)	($0.06)
2030	$0.19	($0.25)	($0.06)

Staff Paper on Option 3C
Tax on Vehicle Miles Traveled

Description

This option looks at the effect of implementing a tax on vehicle miles traveled (VMT) in California of 2 cents per mile for the period 2003-2020.

Background

A tax on VMT would reduce driving and therefore gasoline demand. However, unlike a higher tax imposed on gasoline, a VMT tax does not create an incentive to switch to a more fuel-efficient vehicle to reduce exposure to the tax. In this sense, such a tax is less effective in reducing gasoline demand than a higher gasoline tax.

An obvious hurdle to implementing a VMT tax is collection. A system would have to be developed to collect the fees in as unobtrusive a manner as possible while minimizing possible fraud. Such a tax would likely have to be collected more than once a year so that motorists make the connection between driving and a higher cost of driving; an annual collection might make the connection too remote.

Status

There are currently no serious proposals for per-mile charges in the U.S., aside from those related to pay-as-you-drive auto insurance. See Option 3B (Marginal Cost Pricing for Auto Insurance) for more information.

Assumptions

The Commission's CALCARS model was used to simulate this option. CALCARS is a behaviorally-based vehicle choice, usage, and demand model estimated specifically for California. The model predicts at the household level, using 57 types of households that vary by annual income, number of members, and number of employed members.

The per-mile cost of driving was increased by 2 cents, and this increase affected annual miles driven as well as vehicle demand.[1] Vehicle choice was not affected since the per-mile fee would be the same no matter what type of vehicle was chosen (unlike a higher gasoline tax). The VMT tax was assumed to affect personal vehicles only, as the models used by the Commission for commercial fleet and freight energy demand are currently not behaviorally based.

Revenues from the tax would presumably provide a benefit to California in some form (perhaps through a rebate or a reduction in another type of state tax) and are therefore shown as a benefit in Table 3C-1.

Results

Table 3C-1 displays the results for gasoline reduction from a tax on vehicle miles traveled. Unlike the higher gasoline tax option (Option 3A), the annual percentage decrease in gasoline demand is projected to remain relatively constant, since the VMT tax creates no incentive to purchase a more fuel-efficient vehicle.

Table 3C-1 shows the net benefit results for consumers and the impact on government revenues (in this case a positive net benefit), in present value terms, for 2010, 2020, and 2030, for a 5 percent discount rate. These calculations are net amounts relative to the base case forecast. The negative consumer benefits (also known as the change in consumer surplus) are equal to the higher cost per mile times the new (lower) level of VMT, plus the lost benefits to motorists due to reduced driving (known as the "deadweight" loss to society).

Government revenues increase by the new (lower) level of VMT times two cents, plus the reduction in the cost of highway maintenance (the decrease in VMT times 0.4 cents), minus the excise tax revenues lost due to decreased gasoline consumption. The sum of these two impacts is shown as "Net Benefits" in Table 3C-1, and represents direct benefits excluding the "external" beneficial effects of reduced driving and gasoline demand (e.g., less congestion, less gasoline-related pollution). These entries are negative, but once environmental effects are considered, total direct benefits may be positive.

Key Drivers and Uncertainties

- The key driver for the results described above is the response by households to driving costs predicted by the CALCARS model. The price elasticity of vehicle miles traveled (that is, the percent change in VMT due to a one percent change in driving cost per mile) endogenous to the model is consistent with most other empirical work.

- It is quite possible that there would be additional effects not captured by CALCARS. In the long term, households may respond to the higher cost of driving by changing location (e.g., to be closer to transit or to reduce work commute miles) and government may be more likely to push/promote land use policies that reduce travel costs (e.g., transit oriented development). Such effects would lead to further decreases in travel and fuel use.

[1] The choice of 2 cents per mile was somewhat arbitrary—an amount that promised to have a significant effect on gasoline demand but not so high as to create an onerous financial burden for motorists.

Table 3C-1

Summary of Analysis Results

Option 3C: Tax on Vehicle Miles Traveled

($1.64 per gallon gasoline)

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	($32,560)	$31,231	($1,329)
2002 to 2020	($62,868)	$60,334	($2,534)
2002 to 2030	($84,295)	$80,917	($3,378)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	($5,317)	$5,202	($115)
2020	($6,097)	$5,968	($129)
2030	($7,009)	$6,861	($148)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	3,692	2010	487	3.0%
2002 to 2020	8,885	2020	550	2.9%
2002 to 2030	14,814	2030	631	2.9%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	($11.12)	$10.67	($0.45)
2020	($11.30)	$10.85	($0.45)
2030	($11.32)	$10.88	($0.45)

Staff Paper on Option 3D
Feebates

Description

This analysis looks at the effect of implementing a system of fees and rebates ("feebates") in California for 2003-2030 for new light-duty vehicles to encourage the purchase of more efficient vehicles. The analysis examines two cases. The first case includes a feebate program for California only (State feebate), which includes a "limited" response (in terms of adding additional fuel economy technologies to new cars and light trucks) by auto manufacturers. The second case includes a nationwide feebate system, with a "full" response by manufacturers.

Background

Feebates are a combination of fees and rebates. Feebates are targeted to the sale of new personal vehicles, based on fuel efficiency or emissions of carbon; the analysis presented here examines the effects of a feebate system based on carbon emissions. Vehicles emitting relatively low levels of carbon receive rebates while their high carbon emitting counterparts pay fees. Such a feebate system is also a means of improving fleet average fuel efficiency and therefore reducing overall gasoline consumption, since low-mileage gasoline vehicles emit more carbon per mile.

For this analysis, feebates are structured so that the net feebate receipts of the government are zero; that is, to achieve "revenue neutrality." The fees paid to the government exactly offset the rebates paid by the government on the sales of favored vehicles. The feebate system has a zero point, or "carbon threshold." The threshold is the carbon emissions level at which vehicle purchasers neither receive a rebate nor pay a fee. Those that exceed the threshold, high-carbon vehicles, pay a fee to government. The revenues are used to provide a rebate to those who buy a vehicle that emits below the threshold, a low-carbon vehicle.

For purposes of this analysis, feebates affect consumer welfare in four ways.[1] First, feebates act as a system of taxes and subsidies, which create what economists call a "deadweight" loss to society.[2] Second, the average vehicle owner benefits from reduced expenditures on gasoline. Third, the installation of additional fuel economy technologies by automakers increases the average price of new vehicles (although those receiving a rebate would still pay less than before). Fourth, the increased fuel efficiency offered by manufacturers typically comes at the expense of vehicle performance (represented in the CALCARS model by acceleration and top speed), although this is not always the case.

Status

Feebates were originally proposed by Gordon and Levenson at Lawrence Berkeley Laboratory in 1989.[3] This proposal was termed "DRIVE+" (Demand based Reduction In Vehicle Emissions plus reductions in carbon dioxide) and was developed for possible use in the state of California. Legislation based on the DRIVE+ proposal (and going by the same name) was introduced in the California legislature in 1990. Both houses passed the bill but it was vetoed by then-Governor

Deukmejian. It has been reintroduced several times since then but has never become law. The DRIVE+ proposal was based on tailpipe emissions and emissions of carbon dioxide.

Several versions of feebates have also been proposed at the federal level. This continued interest seems to be based on the twin notions that as a market-based policy, feebates can reduce gasoline demand with a minimum amount of economic distortion, and that the revenue neutrality capability of feebates make such proposals more palatable politically than other more costly programs with similar aims.

The revenue neutrality of feebates has political and administrative appeal. However, it is obvious that some consumers would lose and some would gain economically. In contrast to the government revenue neutrality, the net of the losses and gains by consumers may not be equal to zero.

Assumptions

The Commission's CALCARS model was used to simulate these options. CALCARS is a behaviorally-based vehicle choice, usage, and demand model estimated specifically for California. The model predicts consumer vehicle choice at the household level, using 57 types of households that vary by annual income, number of members, and number of employed members.

The feebate rate used in this analysis is $30,000 per pound of carbon per mile.[4] As an example, using a carbon threshold corresponding to 21 miles per gallon (mpg), the fee for a new light-duty vehicle (LDV) with an efficiency of 15 mpg would be around $3,500, while the rebate paid the to purchaser of a 30-mpg LDV would be roughly $2,600. The threshold level in each year resulted from an iteration process that continued until revenue neutrality was achieved.

This analysis looks at feebates under two scenarios. Case 1 assumes a State feebate with a limited response by automakers, as described in the following section. Case 2 assumes a nationwide system where manufacturers are induced to add fuel economy technologies to almost all models. In a sense, these two cases serve to "bound" the impacts of feebates.

This analysis assumes that there is some response by auto manufacturers to the feebate. In other words, manufacturers are induced to increase the fuel efficiency of at least some models, as the feebate makes this a more profitable strategy.[5] This response is much more pronounced in the nationwide feebate case, where almost all models are affected, than in the State feebate case.

For Case 1 (State feebate), manufacturers were assumed to install additional fuel economy technologies for models whose sales in California exceeded 20,000 in 2001.[6] For these models, technologies were added in the same manner as in the nationwide case (see below). In the CALCARS simulation, which predicts ownership at the size class level, vehicle class characteristics (e.g., fuel efficiency, acceleration) were then changed from those in the base case, based on the proportion of sales in that class attributable to such models.[7]

For Case 2 (nationwide feebate), vehicle manufacturers were assumed to install additional fuel economy technologies as long as the cost of these technologies was less than the change in the feebate resulting from these additions. These changes in vehicle attributes were projected from analysis performed by K.G. Duleep (EEA, Inc.) for a nationwide feebate scenario. The methodology used by Duleep also allowed manufacturers to trade excess credits.

Feebates are assumed to affect personal vehicle decisions only, as the models used by the Commission for commercial fleet and freight energy demand are currently not behaviorally based. Although travel by light-duty commercial vehicles is unaffected, gasoline demand for these vehicles is reduced due to installation of additional fuel economy technologies by auto manufacturers.

Results

Case 1 (State Feebate). Table 3D-1 shows projected cumulative reductions in gasoline demand in the case of a State feebate (limited manufacturer response), as well as reductions for the years 2010, 2020, and 2030 in California in both absolute and percentage terms. In the simulation, average fuel efficiency for new cars reaches 31.1 mpg by 2010 and 32.8 mpg by 2020, compared to 29.8 mpg and 30.1 mpg, respectively, in the base case. For light trucks, the corresponding numbers are 21.5 mpg and 22.6 mpg (compared to 20.4 mpg and 20.7 mpg). Annual reductions in gasoline demand relative to the base case increase over time as more and more of the total LDV fleet in California is affected.

Table 3D-1 also shows the net-benefit results for consumers and the impact on government revenues for 2010, 2020, and 2030. These calculations are net amounts relative to the base case forecast.

Due to manufacturer response, net consumer benefits include both monetary and non-monetary impacts. The monetary impacts are the net of the effects of the change in vehicle purchase prices (including the deadweight loss described above) and the private benefits of reduced fuel consumption. The non-monetary category includes the impact of manufacturer response on vehicle performance due to the feebate. For most years, increased fuel efficiency comes at the expense of vehicle performance (acceleration and top speed) relative to the base case values. In later years, however, the fuel economy technologies installed actually improve vehicle performance (e.g., variable valve timing).

The total change in consumer surplus is positive; the benefits of reduced fuel consumption outweigh the cumulative effects of higher average vehicle prices, the deadweight loss, and the degradation (in most years) in vehicle performance.

The negative entries for government revenues represent the reduction in gasoline excise taxes (less gasoline sold) collected relative to the base case forecast plus the increase in the cost of highway maintenance (the increase in VMT due to the lower cost of driving times 0.4 cents). Net direct benefits (non-environmental) are calculated by summing net consumer benefits and the impact on government revenues.

Table 3D-1 shows the amount of benefit (cost) per gallon of gasoline displaced for 2010, 2020, and 2030. Note that these are non-discounted values and apply to specific years. For example, the entry for "Consumer Benefit" for 2020 is the non-discounted projected gain in consumer surplus for this year divided by the projected reduction in gasoline demand due to the feebate in 2020.

Case 2 (Nationwide Feebate). Table 3D-2 shows projected cumulative reductions in gasoline demand in the case of a nationwide feebate (full manufacturer response), as well as reductions for the years 2010, 2020, and 2030 in California in both absolute and percentage terms. Due to the additional fuel economy technologies being installed on a much more widespread basis, gasoline demand reductions are much more significant than in the State feebate case. In the simulation, average fuel efficiency for new cars reaches 35.0 mpg by 2010 and 41.9 mpg by 2020, compared to 29.8 mpg and 30.1 mpg, respectively, in the base case. For light trucks, the corresponding numbers are 24.3 mpg and 28.5 mpg (compared to 20.4 mpg and 20.7 mpg). As in the previous feebate case, annual reductions in gasoline demand relative to the base case increase over time as more and more of the total LDV fleet in California is affected.

Table 3D-2 also shows the net-benefit results for consumers and the impact on government revenues for 2010, 2020, and 2030. These calculations are net amounts relative to the base case forecast.

As in Case 1, net consumer benefits include both monetary and non-monetary impacts, defined as above. Also as in Case 1, increased fuel efficiency comes at the expense of vehicle performance (acceleration and top speed) relative to the base case values in the early years, while the opposite is true in the later years.

The total impact on consumers (the total change in consumer surplus) is positive and much more significant than in Case 1, due to the more extensive placement of fuel economy technologies by manufacturers. The negative entries for government revenues represent the reduction in gasoline excise taxes (less gasoline sold) collected relative to the base case forecast plus the increase in the cost of highway maintenance (the increase in VMT due to the lower cost of driving times 0.4 cents). Non-environmental direct benefits are calculated by summing net consumer benefits and the impact on government revenues.

Table 3D-2 shows the amount of benefit (cost) per gallon of gasoline displaced for 2010, 2020, and 2030. Note once again that these are non-discounted values and apply to specific years. For example, the entry for "Consumer Benefit" for 2020 is the non-discounted projected gain in consumer surplus for this year divided by the projected reduction in gasoline demand due to the nationwide feebate in 2020.

Key Drivers and Uncertainties

- Given the assumptions made in this analysis, the impacts of a feebate system, both in terms of the reduction in gasoline demand and on the benefits to California vehicle owners, depend heavily on the degree to which auto manufacturers respond. In fact, without any manufacturer response, net consumer benefits may be negative over all time periods, due to the deadweight loss.[8] Therefore, any feebate plan must carefully consider the reaction of automakers.[9]

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[1] There may well be effects not captured here; for example, vehicle weight reductions. In providing a revised set of vehicle attributes for this analysis, K.G. Duleep assumed that the feebate induces manufacturers to reduce slightly the weight of some models to improve fuel efficiency, and weight is not included as a vehicle characteristic in CALCARS. Therefore, to the extent that vehicle owners value weight as an attribute (as a perceived indicator of vehicle safety), the estimated net benefits of a feebate may be overstated. As another example, manufacturer efforts to improve fuel economy may involve the use of composite materials that can potentially prolong the life of a vehicle.

[2] Intuitively, those who switch from a high-carbon to a low-carbon vehicle will not benefit by the full amount of the rebate, since the value to these buyers of the high-carbon vehicle was higher than that of the low-carbon vehicle before the feebate was implemented (see the discussion on the net costs of vehicle incentives in the appendix). In other words, the average buyer who switches to the low-carbon vehicle reaps a benefit less than the amount lost by the high-carbon buyer who provided the rebate. All else equal, when the losses and gains are summed over all new vehicle buyers, the net impact on benefits is negative.

[3] Gordon, D., and L. Levinson, "DRIVE+: A Proposal for California to use Consumer Fees and Rebates to Reduce New Motor Vehicle Emissions and Fuel Consumption", Lawrence Berkeley Laboratory, Berkeley, CA, 1989.

[4] $30,000 is a somewhat arbitrary figure, high enough to have a significant effect on vehicle prices and therefore vehicle purchases. It was used in a previous study by Commission staff that compared the effects of a carbon tax and a feebate that were designed to yield the same reduction in gasoline demand ("A Comparison of Statewide Policies to Reduce Carbon Emissions by Personal Cars and Light-Duty Trucks in California: Carbon Taxes vs. Feebates", October, 1996).

[5] When the addition of a technology to improve fuel efficiency costs less to a manufacturer than the resulting impact on the feebate, the manufacturer can increase profits by adding the technology.

[6] According to K.G. Duleep, if sales of a particular model exceed 20,000 vehicles in a certain area, the manufacturer would likely find it profitable to add fuel economy technologies if faced with a feebate, thus providing a "California version" of the model.

[7] For example, if 50 percent of the sales in a particular class were attributable to models selling more than 20,000 units in 2001, the appropriate vehicle characteristics were changed in each year to the base case values plus 50 percent of the difference between the base case attributes and the national feebate case attributes. The percentage of vehicles in a given class attributable to these models ranged from zero (various classes) to over 80 (the standard pickup class).

[8] This result was indeed found in a previous analysis of feebates ("A Comparison of Statewide Policies to Reduce Carbon Emissions by Personal Cars and Light-Duty Trucks in California: Carbon Taxes vs. Feebates," CEC Staff Report, October 1996).

[9] It should be acknowledged here that any analysis (including the work of K.G. Duleep) designed to estimate the response by automakers to a nationwide feebate, as well as, the cost and effectiveness of installing additional fuel economy technologies, requires engineering and economic judgement, particularly in predicting the impact of combining technologies.

Table 3D-1

Summary of Analysis Results
Option 3D: Feebates
(State Feebate, $1.64 per gallon gasoline)

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$254	($335)	($81)
2002 to 2020	$3,253	($1,376)	$1,877
2002 to 2030	$8,565	($2,485)	$6,080

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$139	($113)	$26
2020	$1,095	($284)	$811
2030	$2,113	($389)	$1,724

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	1,324	2010	389	2.4%
2002 to 2020	7,320	2020	1,023	5.5%
2002 to 2030	17,396	2030	1,429	6.6%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$0.42	($0.34)	$0.08
2020	$1.33	($0.35)	$0.98
2030	$1.88	($0.35)	$1.53

Table 3D-2

Summary of Analysis Results
Option 3D: Feebates
(National Feebate, $1.64 per gallon gasoline)

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$2,081	($808)	$1,273
2002 to 2020	$14,759	($3,814)	$10,945
2002 to 2030	$34,146	($7,246)	$26,900

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$858	($290)	$568
2020	$4,275	($859)	$3,416
2030	$7,481	($1,225)	$6,256

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	3,135	2010	979	6.0%
2002 to 2020	20,255	2020	2,929	15.7%
2002 to 2030	51,123	2030	4,259	19.7%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$1.03	($0.35)	$0.68
2020	$1.75	($0.35)	$1.40
2030	$2.14	($0.35)	$1.79

Staff Paper on Option 3E
Registration Fee Transfer

Description

This option would transfer a portion of annual auto registration fees in California (for 2003-2030) to a marginal cost through a gasoline surcharge.

Background

Economic efficiency and consumer welfare can be improved if the cost of providing a service can be more closely tied to the actual users of that service. A portion of annual auto registration fees is directed toward transportation uses for which actual costs depend on the amount of driving in the state. Benefits may be realized, therefore, by converting this portion to a marginal cost for drivers through a fuel surcharge. This would mean that those that drive more, all else equal, would pay more toward funding our transportation system, while those that drive less would pay less.

Because a registration fee transfer would increase the marginal cost of driving through the fuel surcharge, VMT and gasoline use should decrease. Therefore, the transfer acts as a travel demand measure, and external costs related to both driving (e.g., congestion) and gasoline use (e.g., global warming) would be expected to fall. An advantage of a transfer relative to other measures (such as a VMT tax) is that private costs for the average motorist may be reduced.

Using a VMT tax for this transfer would be more efficient in an economic sense, since motorists would be charged directly for road use. A gasoline surcharge is less direct, since owners of higher efficiency vehicles would pay less, all else equal, than owners of vehicles with lower fuel economy. A fuel surcharge is therefore a “second best” solution. However, the purpose of this analysis is to examine measures to reduce petroleum dependency, and the reduction in gasoline demand should be greater if a gasoline surcharge were used for the transfer.[1] In addition, employing the fuel surcharge provides a convenient collection mechanism.

Status

Many other states earmark state gasoline tax funds toward highway service and maintenance.

Assumptions

The Commission’s CALCARS model was used to simulate this option. CALCARS is a behaviorally-based vehicle choice, usage, and demand model estimated specifically for California. The model predicts at the household level, using 57 types of households that vary by annual income, number of members, and number of employed members.

In this analysis, a portion ($50) of current registration fees is converted into a fuel surcharge. Fifty dollars was roughly the amount of fees per average vehicle directed toward the California

Highway Patrol and state highway maintenance in 2000.[2] This portion is equal to 0.4 cents per mile (assuming average annual mileage of 12,000). To collect this amount per mile required a fuel surcharge of slightly less than 10 cents per gallon. For this option, therefore, vehicle owners would pay $50 less per year in registration fees while paying an increase in the cost of gasoline of around ten cents per gallon.

Note that the critical assumption that must be made is that the cost of the Highway Patrol and of state highway construction and maintenance is proportional to vehicle miles traveled.

The registration fee transfer was assumed to affect personal vehicles only, as the models used by the Commission for commercial fleet and freight energy demand are currently not behaviorally based.

Results

Table 3E-1 displays the results for gasoline reduction from a registration fee transfer. Similar to the gasoline tax analysis, annual reductions in gasoline demand relative to the base case increase over time as motorists switch to more efficient vehicle to reduce exposure to higher fuel costs (although the effect is much slighter in this case). Percentage reductions in VMT (not shown) are smaller than reductions in gasoline demand, reflecting the incentive to purchase vehicles with higher fuel efficiency created by higher gasoline prices.[3] More detailed results and discussions are located in Attachments A and B.

Table 3E-1 also shows the net-benefit results for consumers and the impact on government revenues in present value terms, for 2010, 2020, and 2030. These calculations are net amounts relative to the base case forecast.

The gain in economic efficiency that would be predicted by theory is reflected in the positive net benefits for consumers shown in the table. These benefits are a net of the reduction in direct payments for registration fees and the burden of higher fuel costs. Effectively, the average motorist now incorporates highway costs in his marginal driving decisions and is able to reduce his total costs by driving less—an option not available without a registration fee transfer.

Government revenues decrease by the loss in excise taxes due to reduced gasoline demand, minus the reduction in the cost of highway maintenance (the decrease in VMT times 0.4 cents). The sum of these two impacts is shown as "Net Benefits," and represents direct benefits excluding the "external" beneficial effects of reduced driving and gasoline demand (e.g., less congestion, less gasoline-related pollution). These entries are negative, but once environmental effects are considered, total direct benefits may be positive.

Finally, Table 3E-1 shows the amount of benefit (cost) per gallon of gasoline displaced for 2010, 2020, and 2030. Note that these are non-discounted values and apply to specific years. For example, the entry for "Consumer Benefit" for 2020 is the non-discounted projected gain in consumer surplus for this year divided by the projected reduction in gasoline demand due to the higher tax in 2020.

Key Drivers and Uncertainties

The responsiveness of motorists to higher fuel prices will determine the magnitude of net consumer benefits. The more responsive are drivers, the higher the level of net consumer benefits (and the higher the reduction in VMT and gasoline use). However, consumer net benefits will always be positive, given the assumptions made here (they would be zero if there were absolutely no response to higher fuel costs). That is, the average consumer will always be better off. Of course, this does not mean that every motorist would be better off. Those who drive many more miles than the average could end up with a higher total cost of driving, and drivers of vehicles with very low fuel efficiency could be adversely affected, unless a mechanism were implemented to address differences in fuel efficiency.

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[1] This is so because a gasoline surcharge increases the incentive to purchase a vehicle with high fuel efficiency.

[2] *Fast Facts*, Department of Motor Vehicles, 2001.

[3] This result represents a "rebound" effect. The switch to more efficient vehicles reduces the impact of higher gasoline prices on vehicle fuel cost per mile.

Table 3E-1

Summary of Analysis Results

Option 3E: Registration Fee Transfer

($1.64 per gallon gasoline)

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$21	($180)	($159)
2002 to 2020	$40	($370)	($330)
2002 to 2030	$54	($511)	($457)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$4	($32)	($29)
2020	$4	($40)	($36)
2030	$5	($48)	($43)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	853	2010	120	0.7%
2002 to 2020	2,201	2020	147	0.8%
2002 to 2030	3,813	2030	174	0.8%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$0.03	($0.27)	($0.24)
2020	$0.03	($0.27)	($0.24)
2030	$0.03	($0.27)	($0.24)

Staff Paper on Option 3F
Purchase Incentives for Efficient Vehicles

Description

This option involves government providing a purchase incentive for the most fuel-efficient vehicles in each class at the time of sale to reduce the purchase price and thus, increase the relative value of fuel-efficient vehicles compared to average fuel economy vehicles.

Background

Incentives are provided to consumers to encourage the purchase of specific products. Consumer incentives can be provided in the form of tax credits or deductions, rebates and the related fee-bates, or cash incentives directly to the consumer at the time of purchase, or to the manufacturer before the sale.

Direct consumer incentives are a means to increase the market share of fuel-efficient vehicle technologies. The direct consumer incentive approach, unlike a tax credit, is not dependent on the income of the purchaser. The incentive can be obtained even if the purchaser does not have any taxable income. These various forms of incentives have at least one commonality – the funding source is tax based and as such they reduce or return taxes paid by consumers.

From case studies performed using the CALCARS model to estimate the demand for transportation fuels, the staff has found that the model projects at least a 10 percent increase in vehicle sales by vehicle class when the vehicle's purchase price is reduced by 10 percent. Thus, if a consumer is provided a monetary incentive for the purchase of best-in-class fuel economy vehicles, the number of vehicles sold can be increased beyond the level predicted under the base case demand analysis. The amount of reduced fuel consumption can then be estimated using the purchase price and sales rate relationship predicted by the CALCARS model.

The best fuel efficient vehicles currently available on the market have the potential to reduce California's gasoline demand by up to 3 billion gallons per year. This level of fuel savings would be achieved if all vehicles purchased each year had the same fuel economy as the "best-in-class" vehicle in terms of fuel economy.

Status

The average vehicle mileage calculated from passenger cars and light-duty truck models in the U.S. Department of Energy Fuel Economy Guide for Model Year 2002 is 21.5 miles per gallon gasoline.[1] From the same reference, the most efficient vehicle in each vehicle class is approximately 28 percent more efficient than the average of all vehicles available. If consumers purchased the most efficient vehicles in each class, the average fuel economy of vehicles operating in California would eventually increase from approximately 21.5 to 28 miles per gallon.

Today, about 1.5 million new light-duty vehicles are sold annually in California. Approximately 30 percent of these vehicles (441,000) can be categorized with best-in-class fuel economy performance.[2]

Assumptions

Assuming an incentive program could increase the rate of purchase of the most fuel-efficient vehicles, this scenario assumes that a 10 percent purchase incentive for best-in-class vehicles would increase annual sales of such vehicles by 10 percent.

The scenario in this analysis begins in 2003 with incentives being provided to increase the sale of best-in-class fuel economy vehicles. The incentive results in an annual "best-in-class fleet" population that is 10 percent larger than the new annual population under base case conditions, growing by 2 percent every model year.

At the current fleet growth rate of 2 percent per year as calculated from Department of Motor Vehicle registration data, staff calculates that with an increase in efficient vehicles purchases of 10 percent beginning in 2003, approximately one million additional vehicles would be achieving this higher fuel economy by 2030.[3]

Using manufacturer's suggested retail prices for vehicle prices, staff calculated the average price for the most efficient vehicle in class to be about $19,000.[4] This is $2,400 less than the average vehicle price. However, staff assumed that the potential reduced vehicle cost of a best-in-class vehicle is a dollar-for-dollar reduced benefit to the consumer (i.e., between two choices, the consumer would not buy a more expensive vehicle unless the vehicle provided greater benefits than the less expensive choice). Thus, this potential dollar savings is not considered a benefit in the economic comparison performed for this analysis.

Staff assumed that to achieve the 10 percent growth in the sale of best-in-class vehicles, a consumer would need a $1,900 incentive in order to purchase the more efficient vehicle in lieu of the average vehicle in class. The incentive amount is 10 percent of the average manufacturer's suggested retail price for best-in-class vehicle models. This amount makes the consumer "feel better off" when purchasing the vehicle, even though it might cause the loss of non-monetary benefits provided by another vehicle that would otherwise have been purchased. For some consumers, nearly the full incentive could be considered a benefit. However, others may view the incentive amount as being just enough to overcome the loss of benefits provided by the other vehicle being considered. On average, the consumer benefit derived from the incentive is assumed to be one-half of the incentive amount.

Results

Table 3F-1 displays the results for the economic comparisons and projected gasoline reductions from purchase incentives for efficient vehicles.

The consumer benefits can be relatively large since each consumer purchasing a best-in-class fuel economy vehicle will receive an incentive. Consumers experience a present value benefit (savings) that is estimated to range from about $6.3 to $17 billion over the time periods evaluated. Consumer benefit increases over time. The benefit results from the incentive value. The individual consumer benefit value for the incentive is $950 or $1,900. Free riders receive the larger benefit.

Although the additional consumers who purchase a higher fuel economy vehicle will expend less money for fuel, this savings is not considered a consumer benefit for these purchasers. In the absence of a purchase incentive, these consumers would have purchased a lower fuel economy vehicle because this vehicle's benefits were greater in value than the fuel savings offered by the higher fuel economy vehicle. For the incremental purchasers of best-in-class fuel economy vehicles in this option, the benefit of reduced fuel expenses is offset by the loss of other vehicle benefits provided by the competing vehicle choice.

Since the consumer benefit in this option does not depend on the expense for fuel, the results for the economic metrics do not change with fuel price.

The change in government revenue is estimated to be a present value loss due to reduced collection of fuel excise taxes and expenditures for vehicle incentives. These losses range from about $6.7 to $18.1 billion over the time periods evaluated. Losses increase over time but are not dependent on the gasoline price in this analysis.

The combined effect of the consumer benefit and change in government revenue is a present value net benefit (loss) that ranges from about $357 million to $1.1 billion. The loss in net benefits increases over time.

Single-year economic results shown are similar to the present value outcomes. Consumers accrue monetary benefits. The benefits increase over time. Net benefits, however, show a monetary loss. The single-year results do not use present values.

Based upon current vehicle offerings, the amount of reduced gasoline consumption due to an incentive program for the purchase of efficient vehicles is estimated to range from 0.3 percent to 0.6 percent of the annual base case demand.

This option is estimated to save money for consumers for each gallon of gasoline displaced. The savings range from $$11.97 to $20.99 per gallon. These relatively high values are caused by the magnitude of the incentive value received by consumers. However, the vehicle incentive and reduced government revenue from fuel excise taxes causes government losses for each gallon of gasoline displaced, ranging from $12.87 to $22.33 per gallon. The net benefit is a loss per gallon displaced, ranging from $0.90 to $1.33 per gallon. These results do not use present values.

Key Drivers and Uncertainties

- There is uncertainty in the number of people who would have purchased the best-in-class efficient vehicle without the incentive or a smaller incentive.

- There is uncertainty in the number of people who will change their purchase decision for the incentive proposed.

- There is uncertainty in the projected fuel savings for each vehicle class in future years as the fuel savings is directly affected by the fuel economy of the vehicle models offered and by the fuel economy of the vehicle that was being considered instead of the best-in-class vehicle.

  Although the analysis assumed that the consumer influenced by the incentive would normally have purchased an average fuel economy vehicle from the same class, the consumer taking the incentive may have been considering a vehicle with a fuel economy level above the average but slightly below the best-in-class level. The fuel reduction in this case would be less than predicted in the analysis since the difference in fuel economy is not as large.

  Another possible outcome involves the consumer taking the incentive to buy a different class of vehicle (one that was still best-in-class) that had a lower fuel economy than the class considered in the base case. In this latter case, the fuel consumption would not decrease, but increase. An incentive program could be designed, however, to limit these undesirable types of transactions.

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[1] U.S. Department of Energy, Model Year 2002 Fuel Economy Guide, www.fueleconomy.gov/feg/feg2000.htm.

[2] California Department of Motor Vehicles, Vehicle Registration (VR) Data Base, California Energy commission VR Processing Methodology, 04-01-02 run date, Gary Occhiuzzo.

[3] Ibid.

[4] New Vehicle Pricing, www.edmunds.com/new/index/index.html.

Table 3F-1

Summary of Analysis Results
Option 3F: Purchase Incentives for Efficient Vehicles

Present Value Million 2001 Dollars Saved Over Time Period "( )" Equals Cost

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2002 to 2010	$6,315	($6,672)	($357)
2002 to 2020	$12,404	($13,197)	($793)
2002 to 2030	$16,961	($18,098)	($1,138)

Single Year Savings in Millions of 2001 Dollars

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$1,051	($1,118)	($67)
2020	$1,282	($1,379)	($97)
2030	$1,562	($1,680)	($118)

Fuel Displacement Over Time Period Indicated (Million Gallons)

	(Cumulative Million Gals)		(Million Gallons)	Percent Base Case
2002 to 2010	220	2010	50	0.3%
2002 to 2020	1,085	2020	107	0.5%
2002 to 2030	2,281	2030	131	0.6%

2001 Dollars Per Gallon of Conventional Fuel Displaced

	Net Consumer Benefits	Change in Gov't Revenue	Net Benefits
2010	$20.99	($22.33)	($1.33)
2020	$11.97	($12.87)	($0.90)
2030	$11.97	($12.87)	($0.90)